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Enhancing Engineering Education Using Mobile Augmented Devices

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ENHANCING ENGINEERING EDUCATION USING MOBILE AUGMENTED DEVICES

A Dissertation submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

By

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I HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER MY SUPERVISION BY Kushal Abhyankar ENTITLED Enhancing Engineering Education Using Mobile Augmented Devices. BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Doctor of Philosophy.

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Abstract

Abhyankar, Kushal. Ph.D., Engineering Ph.D. Program, Department of Biomedical, Industrial and Human Factors Engineering, Wright State University, 2017. Enhancing Engineering Education Using Mobile Augmented Devices.

Employing effective and modern educational systems that support augmented learning methods such as mobile-based learning, may offer a promising solution to lowering dropout rates and to improving learning interests in engineering education. Mobile-based learning is capturing tremendous attention due to the affordances mobile devices can offer. This project outlines efforts to integrate mobile-based educational technology into the classroom. Leveraging the affordances, we designed a mobile augmented education tool for basic math and physics concepts that allows access to information and additional learning content within the context of classroom learning. Results from the study indicate that there is significant improvement in overall performance in mathematics and physics for all students. Based on the form-factor analysis, we found that the students highly preferred 7-inch tablet devices for the overall presentation of the content and portability. This research aims to present the framework and design guidelines for mobile-based augmented learning tools intended to enhance engineering education. The design guidelines presented in this research can universally be applied for any classroom assisting mobile augmented education tool. Structural equation model analysis of the questionnaire based data collected from the students also suggests that the designed model predicts the behavioral intention of the test participants accurately. It also proves the validity and reliability of the collected data. Model development process forms a systematic metric to understand the performance of mobile augmented education tools and develops a framework to assess the students' overall attitude towards it. According to the horizon report, as education practices move from formal to informal and collaborative, mobile devices are playing a major role in the transition process. This research is an attempt to provide students with an ability to leverage their day to day devices to assist them with learning content for better knowledge acquisition.

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Acknowledgement

I dedicate my work to my mother, Mrs. Rekha Abhyankar, my father, Mr. Dinesh Abhyankar, my wife Mrs. Supriya Abhyankar, my daughter Shanaaya Abhyankar and to the memories of my sister Shalaka Abhyankar, my grandmother, Sudha Taskar, and my uncle and mentor, Jayant Chitre. My sincere thanks to my in-laws Dr. Sunil Deshpande, Mrs. Meenal Deshpande, Ms. Sujaya Deshpande and my whole family; Mr. and Mrs. Bendre, their daughters, Diya and Nitya. I also would like to extend my thanks to my friends Deeptaunshu, Tushar, Rohit, Veena, Aarti, Ayush, Ravi, Ramya, Sandeep, Jaswandi, Rahul Boduluri, Kelkars, Umranis and Kulkarnis. I also want to thank three special persons in my life, Dr. S. Prabhala, Dr. S. Narayanan and William Zembrodt. I also want to express my gratitude toward Nitin and Parul Soni, my aunts and uncles, Mrs. Surekha Deshpande, Mr.Deepak Deshpande, Mr. Satish Taskar, Mrs. Mangal Taskar, and Dr. Kiran Chitre. My parents always taught me to be honest and focused, my wife kept me on the path, believed in me, and all others helped me immensely to stay on.

1 INTRODUCTION

There is an increasing demand for qualified engineers in the ever-advancing engineering industry. Providing the right skill-set and training to engineers to fulfill the needs of the industry has always been a primary goal of the engineering education system. While college enrollment numbers continue to rise in the U.S., the number of students graduating from engineering programs is on the decline [28]. Since 1993, The Science and Engineering Indicators, a biennial report by National Science Foundation, has indicated a constant increase in attrition in STEM enrollment and a decrease in the number of successful graduates for various engineering majors [104]. In 2013, the National Center for Education Statistics reported alarming attrition rates in engineering degree programs as well. Figure 1.1 through 1.5 represent attrition rates in overall STEM programs and in engineering degree programs according to the statistical analysis report provided by the US department of education [28].

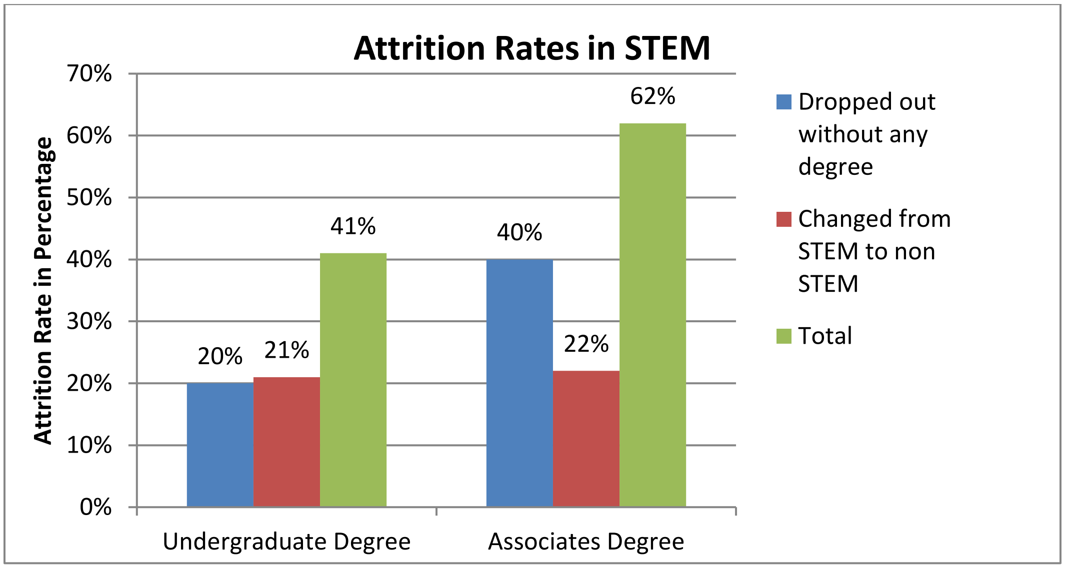

Figure 1.1: Attrition Rates in STEM courses over years 2003-2009 [28]

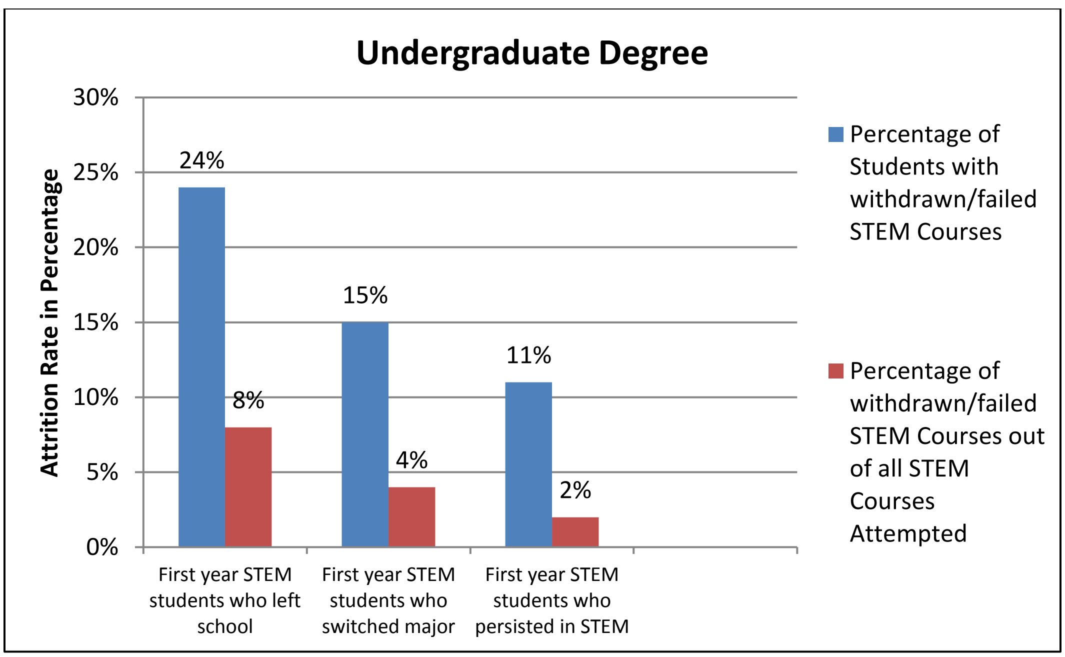

Figure 1.2: First Year Attrition Rates in STEM – Undergraduate Degree over years 2003-2009 [28]

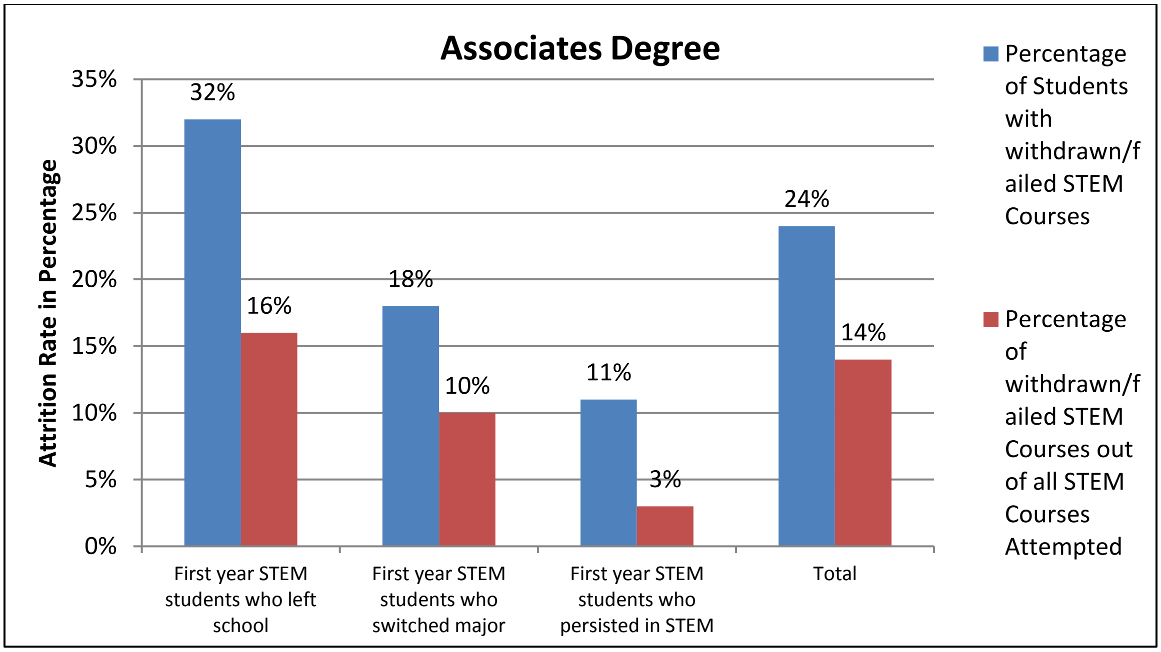

Figure 1.3: First Year Attrition Rates in STEM – Associates Degree over years 2003-2009 [28]

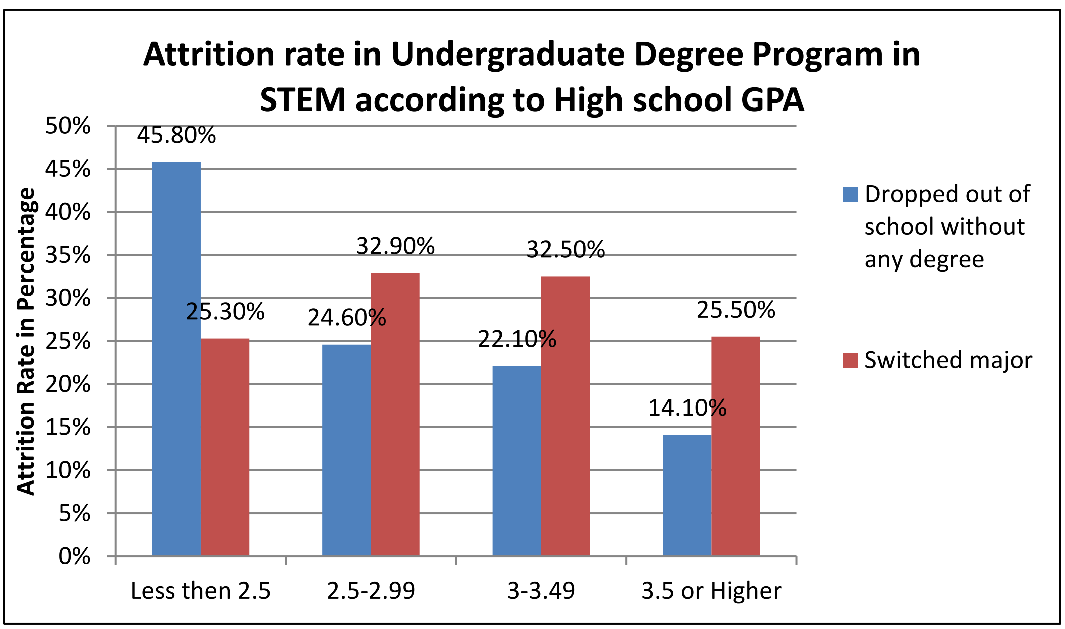

Figure 1.4: Attrition Rates in STEM as per High School GPA – Undergraduate Degree over years 2003-2009 [28]

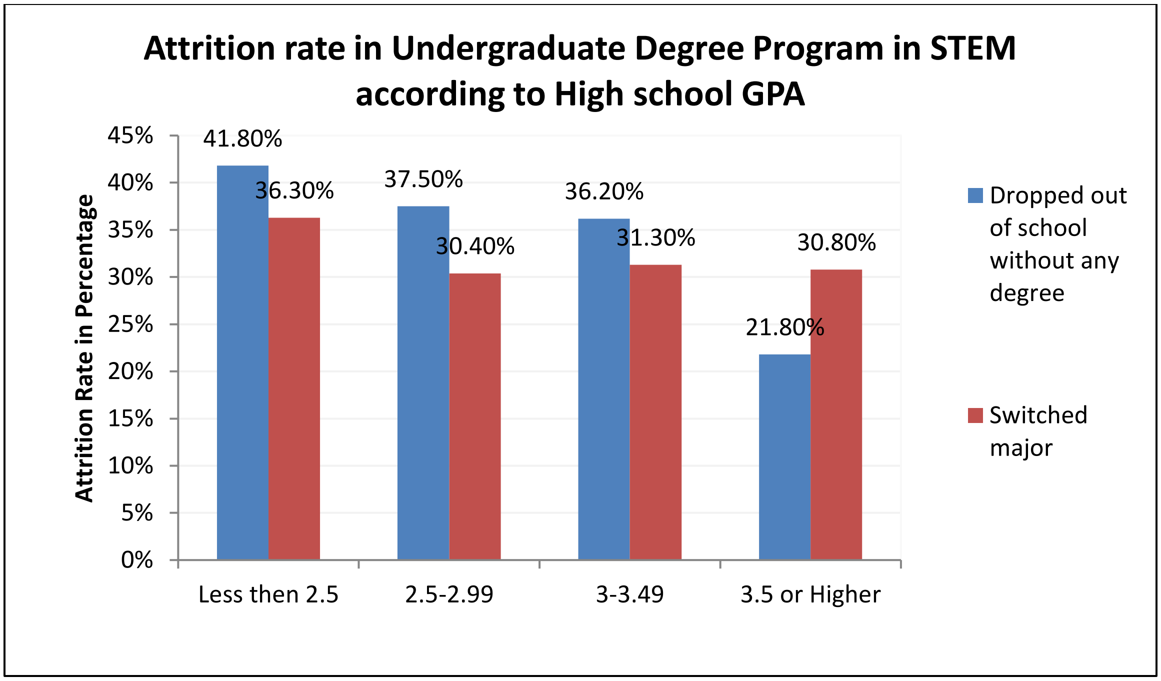

Figure 1.5: Attrition Rates in STEM as per High School GPA – Associates Degree over years 2003-2009 [28]

According to Geisinger & Raman, Becker, Grau-Valldosera & Minguillón, and Wallace & Mutooni, there is a direct correlation between the traditional learning mechanism and the abstract nature of engineering concepts associated with engineering students who dropout [16][59][156]. Education styles within engineering schools are mostly formal and traditional. The definition of the modern all rounded engineer is given by the Accreditation Board for Engineering and Technology (ABET). Among this criteria for successful engineering programs (Criteria for Accrediting Engineering Programs, 2012 – 2017), students need to demonstrate an ability to apply knowledge of mathematics, science, and engineering, as well as a deep understanding of the impact of engineering solutions in a global, economic, environmental, and societal context. Students should be able to apply these concepts in a multidisciplinary team [1][2][3][4]. Georke, and Becker have proved that purely formal, classroom-based learning falls short when educating large groups of engineering students and results in an increased number of drop outs [16][57]. In order to achieve a comprehensive understanding of engineering concepts, students commonly have to look for alternative ways to educate themselves in addition to their classroom-based learning. These non-traditional practices allow students to think outside the box of conventional learning. This helps to improve the overall educational experience by catering to the learning style of the individual.

Most engineering schools still employ teaching practices that involve classic classroom instruction-teacher interactions. These kinds of interactions do not allow students to learn and experience real world problems where implementation of classroom learnt theoretical concepts is necessary and therefore, the educational experience becomes less interesting and the nature of the concepts remain abstract [40][41][45] [48][51]. Hence, there is a need to understand and provide teaching practices that allow students to understand abstract concepts in engineering. As part of the development of such education systems, much of the focus is drawn towards the introduction of informal learning practices in the engineering curriculum [49][51]. Informal learning styles allow for problem-based learning, active communication with peers and instructors, technology assistance, and collaboration. Due to the deep roots of formal teaching practices within traditional engineering schools, a total paradigm shift from formal to informal practices may not be possible. Technology integration in educational practices could be thought of as a viable solution to bridging the gap between the two teaching practices. While there are examples of the use of technology that have helped resolve some of the difficulties in educational settings, these are silo solutions [34][96][97][124][125][126][127][139][140]. There is a strong need to understand how to integrate technology into educational practices in a way that makes learning more efficient for students. Therefore, understanding the affordances of technology integration and developing guidelines to assist in the development of supportive learning avenues and alternatives is necessary.

The focus of this research was to understand the effectiveness of technology integration for knowledge acquisition and for developing design guidelines to explore the affordances of mobile technology as an augmented learning tool for STEM education. Specific research objectives include:

1. Understanding the challenges present in knowledge acquisition of engineering concepts.

2. Developing a mobile-based augmented learning system to help students learn the basic engineering concepts in mathematics and physics supporting in-class learning. Also, assessing the performance and effectiveness of mobile technology intervention in the process of learning basic engineering concepts.

3. Developing a taxonomy of design guidelines to facilitate the development of supportive content for engineering students on mobile devices.

4. Defining a framework for a User-centered Technology Acceptance Model that allows validation of the design and can predict the behavioral intention of students who would utilize this mobile technology as a technology assistant.

In order to address the research objectives in a systematic manner a research framework was developed as shown in Figure 1.6. This framework details the various steps conducted towards a systematic methodology to identify and address the challenges students experience in learning engineering subjects.

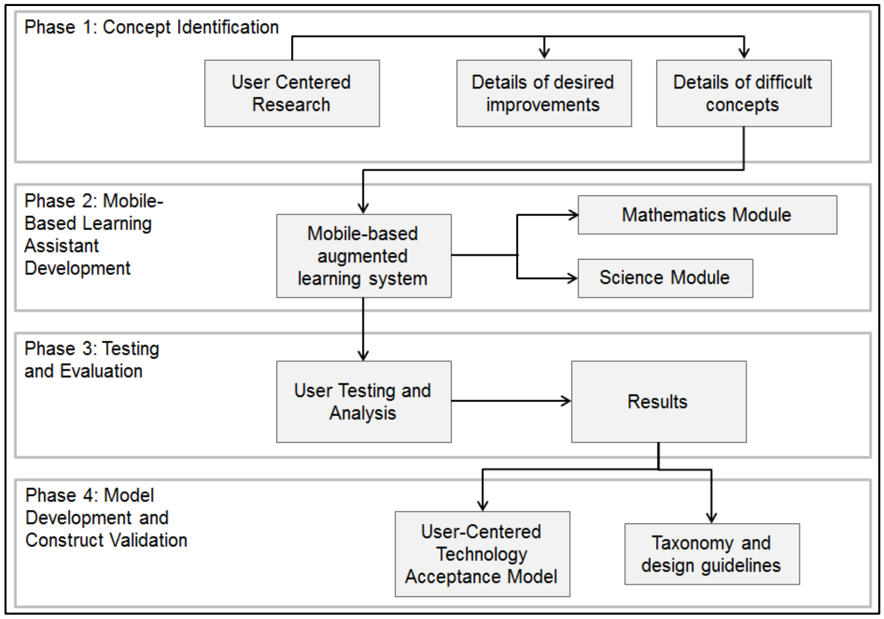

Figure 1.6: Research Framework

As shown in Figure 1.6, the research framework for this study was divided in four phases – Phase 1) Concept Identification; Phase 2) Mobile-Based Augmented Learning Assistant Development; Phase 3) Testing and Evaluation; Phase 4) Model Development and Constructs Validation. Phase 1 included detailed user-centered research to identify some of the most difficult engineering subjects, a detailed list of difficulties students face, as well as desired improvements in engineering education. In Phase 2, we developed the mobile-based augmented learning system. With the mobile-based augmented learning system, we designed mathematics and science (physics) classroom material with additional augmented learning assisting material in the instantiation stage. In Phase 3, testing was conducted on mobile augmented learning system participants with formal tests and questionnaire-based attitudinal measurements that allowed us to confirm the effectiveness of the technology integration as well as validity and reliability of the collected data. Post-test qualitative interviews helped us understand usability and desirability of individual leaning assistants.

These interviews also helped in formation of overall design guidelines for the mobile augmented learning assistant designs. In Phase 4, we designed the ‘User-centered Technology Acceptance Model’. This design was used for modeling and testing the validity of the data collected to address the basic attitudinal measurements of the student participants toward their behavioral intention.

This overall framework is a result of individual research and development activities. This framework is scalable to any systematic mobile augmented learning assistant development and the testing for all-round effectiveness.

This dissertation is divided into 11 chapters. Chapter 2 presents the research background in review of the theory relevant to creating the framework. Chapter 3 (Concept identification) discusses the exploratory phase of the research. In Chapter 4, the research objective and hypotheses are presented. Chapter 5 discusses the mobile system design. Chapters 6 and 7 discuss the experiments conducted to examine and validate the framework. Chapter 8 presents the qualitative data collected from the participants to understand the preferred mobile device sizes and interesting learning assistants. Chapter 9 discusses the model development based on the quantifiable data collected. The results discussion is presented in Chapter 10. Lastly, the theoretical contributions and applications of this work are laid out in Chapter 11.

2 LITERATURE REVIEW

2.1 MOBILE-BASED LEARNING

The pervasiveness of mobile devices is changing the way people interact with content and their surroundings. As the processing power of smartphones, smart watches, and tablets continue to increase dramatically, mobile learning or m-learning, enables learners to access materials anywhere, across multiple devices. Convenience is driving demand for this strategy, with the potential for new mobile-enhanced delivery models that can increase access to education. Instructors are harnessing the capabilities of mobile devices to foster deeper learning experiences by creating new opportunities for students to connect with course content. Mobile apps, for example, allow two-way communication in real time, helping educators efficiently respond to student needs. This development is impacting both the delivery and creation of educational content. Surveys of the field have revealed that instructors still need technical and pedagogical support from their institutions in integrating mobile devices into their curricula [31][72]. The Horizon Report, 2017 [72] has highlighted mobile technology as a prime form of technology that will be consumed in the educational field in next couple of years. Technology developers and visionary educators believe that mobile technology is going to be an inalienable part of human life for information exchange.

Through the same vision, education researchers have begun exploring the potential of mobile technology for improving teaching and learning practices in education. Several researches have documented the implementation of mobile-based learning ecosystems [33][34][94][95][105][123][124][125][138][139][143].

Mobile learning devices can act as excellent catalysts in a rich active learning environment. Active learners are expected to act in the physical world (classrooms, projects, real world problem solving), access resources (text, sound or videos on the internet), and interact with others. Mobile devices can act as excellent mediators between the individual learner and his or her social and physical environment. As e-learning has started extending its branches, m-learning is coming up as a specialized branch [96]. Matthee and Liebenberg [97][98] have implemented mobile devices as mediating devices for basic mathematics courses for teenagers. The research scenario is based in South Africa. While PC-based education is limited there is a massive population of people using mobile devices for communication and education. The application is termed as 'Mobi'; a mathematics support tool that teaches students about the basic concepts of mathematics in an active learning space. MyArtSpace™ is another mobile-based learning system for museums that is developed keeping the cohort of school students in mind. MyArtSpace™ software shows multimedia presentations of museum exhibits, takes photos, records voices, takes notes, and tells the user who else has viewed the exhibit. As backup, the content is stored to a server which maintains a personal record of student visits [33]. The research conducted by Stewart highlights the need for educators and education researchers to work closely together for the common good. This research combines socio-cultural perspectives with the context of learning materials and different pedagogical methods. The framework is designed for student-led active learning practices. This research and the framework have resulted in a significant increase in the level of student engagement [33][122][123][124][125][138][144][145][146]..

Bressler and Kahr-Hoijland [26] documented two interesting parallel projects in a mobile-based general science teaching area. The First project described is called Science Now, Science Everywhere (SNSE). SNSE is dedicated to learning about museum artifacts and animals. SNSE allows students to learn about these artifacts through voice narratives and SMS. Using SMS, visitors can update the information on exhibit displays. The second project, called ego-trap, allows student participants to learn about the science exhibits through a series of question-answer games. Although the area of application of these systems is different than engineering or core science, the application of mobile devices was noteworthy. The primary reason why it attracted attention was that the experimenters were able to use the mobile devices to effectively increase student's interest in learning.[27]. Arevalo, et. al [15] and Reynolds [117] designed a training program for dentists who were mobile users and provided learning content on these devices. The extension of this system is a model-based virtual environment supported system for dentists' training. Georke and Oliver [57] attempted to define the uses of mobile devices for university students. The focus of their research was to understand how mobile devices can be used as personal assistants. Their findings on PDA based research highlighted the use of mobile devices as an accessory or a secondary learning device. Students visualized these mobile devices as an addendum but not as primary learning devices. This research was carried out in 2005, before the birth of the mobile iOS and Android systems. The use of mobile devices in human life has grown from an accessory to an inseparable pervasive device. Mobile phones and tablets are just a few of the major devices that support reading practices and serve as a primary means of communication. There is limited evidence available to assess the role of the latest mobile devices as education assistants in engineering institutions. Therefore, through this research project, we attempt to; a) assess the influence of a mobile learning tool for knowledge acquisition using user-centered design methods; b) measure the inclination towards acceptance of the mobile technology for in class and outside-the-classroom learning settings; c) identify the level of knowledge acquisition using mobile-assisted teaching methods.

Hartnell-Young [63][64], Hartnell-Young and Vetere [66], and Hartnell-Young and Heym [65], highlight the necessity of educators and researchers to work hand-in-hand in order to implement mobile-based learning practices. Kukulska-Hulme [89][90] has demonstrated the effectiveness of the use of smartphones in informal and self-learning settings. These tools are essential in the development of hands on skills, professional development; solving real world problems with ease and so on. Mobile devices are useful for in-travel multimedia support for learning, reading, and editing when we are on the move. Studies conducted by Kukulska-Hulme [89][90][91][122][160] through multiple collaborations have integrated the mobile-based learning practices for several learning trainings as well as teaching aids. A primary focus of this research is around the deep understanding of a) content delivery, b) knowledge transfer, c) content presentation, d) social interaction with the help of mobile devices and e) collaborative learning opportunities through the use of mobile devices. Another important part of this research was to identify the avenues needed to integrate mobile technology with flexible yet effective teaching practices. In order to arrive at conclusive standards, experiments were conducted with the help of PDAs and palm computers. The standards and requirements set by this research, for mobile-based learning, are universal. Lefoe [93] described the importance of implementing scenario-based learning in mobile-based informal learning pedagogies. Mann [96] highlighted the need to utilize mobile devices within learning contexts as mediators .Research activity documented by Rentoul et al [116], Klopfer et.al [84], and Zembal-Saul et al [164] informs us that the practice of mobile-based learning is available as a growing group of documented case studies of innovative practices of technology supported active learning [85][116][164] . In order to understand student engagement and acceptance level of mobile-based active learning practices, Sharples and Taylor [124][125] conducted detailed ethnographic studies over students using mobile technology as a mediating device for learning. This ethnographic research identified the important role of mobile technology as a learning aid. Types of learning aids included: video streams, SMS services, and reading assistants.

In another example, Thompson and Stewart [136] presented the mobile-based learning assistant system called Jigsaw which specializes in science education for primary and secondary school students in the UK. This particular technology utilizes tablets, PCs, cameras, USB drives, and Wi-Fi connectivity. Students used these technologies while collecting information about the local environment to create products such as databases for plant species. The successful application of this strategy enabled teachers to incorporate mobile learning into their classrooms. Mobile services offer a multitude of learning opportunities and aids for improved reading practices. Podcasts are one of the services available on mobile devices [136] . Research carried out by Clark, Sutton-Brady, Scott, and Taylor [29] showed a significant affinity for the mobile podcast based learning content. The results also showed a significant improvement in the students' long term knowledge retention levels through this mode of learning. Service enriched mobile devices are an excellent option for on-the-spot learning which is an inseparable form of active learning that is often incorporated in jobs and training situations. With the help of Information and Communication Technologies (ICT), the experience of on-the-spot training can be enhanced. Ferry [52] reports the use of cell phone devices rich with multiple multimedia, communication, and document services in training teachers for primary schools. Herrington and Herrington [69] presented with a similar system, approached from a design perspective, in the area of teachers' education. They also strived to extend the utilization of mobile devices in higher education within multiple research applications. Herrington et Al. [70] studied the implementation of mobile learning devices such as palm smart phones and iPods for learning support with mp3 recordings in the space of educators' training. Kervin and Mantei [80] also presented research on the use of iPods in the area of educator training.

Language learning is another field that is enriched by the assistance of mobile devices. Pearson [107] developed a family oriented English language learning tool, using mobile phones, for eastern European immigrants. These mobile-based learning practices showed significant improvements in language skills of test subjects. Improvements were seen in areas such as: speaking, writing, reading, and also understanding the spoken language. Hwang, Chen and Chen [74] developed a mobile-based scaffolding tool for the development of English writing skills in those who seek to learn English as a foreign language. Deng and Shao [38] presented a mobile-based English vocabulary learning tool which led to better confidence as well as improved self-direction towards learning. Students demonstrated higher acceptance levels of mobile devices as scaffolding tools. These results reflect a high sustainability of mobile-based active learning practices in vocabulary learning. Petersen, Sell, and Watts [109] designed a mobile-based language learning aid called Cloudbank, which supports a repository for words and expressions that can be shared by several users. The experiment was carried out at an international school using a mobile application designed to support language learning. This was accomplished by teaching students figures of speech in the English language. Mobility and accessibility of the content and information, appropriation of the technology, collaboration among students, additional content availability, and ownership of the learning content were common outcomes from this experiment.

In the field of science education, research on mobile-based educational practices looks promising. Johnson, Davison and Moralejo [76] presented a mobile–based learning platform for nursing students who learned English as a foreign language. In international universities, many times, the support of manuals and textbooks are forbidden. Nursing education demands on-the-spot and just-in-time learning. Mobile devices are best suited for this purpose. The mobile supported just-in-time learning setting has proven to be extremely useful in student learning as well as increasing self-efficacy towards learning practices. Ernst and Harrison [39] developed SBLi™ a mobile device interface that delivered knowledge to the biomedical students learning in just-in-time settings. SBLi™ delivers short 90 second informational videos on several information snippets in the physiology practical classes. Contextual learning is another widely researched field. In the laboratory setting, SBLi™ offers high impact active learning opportunities vs. formal teaching environments at convenient times. This system was designed to deliver context aware content for the learners in several different physical settings. Tan, Zhang, Kinshuk and McGreal [134] designed an innovative 5R adaptation framework to deliver context aware learning content to students. This framework has been tested for its effectiveness for field trips' in outdoor education settings. The subsequent content is generated considering: location, time, learner, and type of mobile device in use. Morimoto et Al. [101] showcased a dynamic content construction model for the generation of learning content. Generated content was specific to the mobile device and based on the form factor size, learner ability, and contextual adaptability. Though the authors have not produced conclusive experimental results, the development of the auto-learning content generating model is a positive initiative from the Japanese society of science promotion. Cochrane, Narayan and Oldfield [30] integrated iPads in several engineering streams over multiple longitudinal studies that examined the effectiveness of technology integration. The study was carried out in multiple streams of education over multiple time periods. For each education stream, the mobile-based learning platform presented a different set of affordances. The tested streams were architecture, music education, business education, and civil engineering education. The pedagogy was not modified but devices were provided in the classroom to provide support for student needs such as: additional content searches and illustrations. Ipads were not used in class for the primary content presentation. Besides calculators, all services were standard web-based existing applications such as google docs, microbloggers, and polling. In this line of research, multiple observational studies have been performed for landscape design and product design degrees. There has been only one study with respect to engineering, which does not support hosting primary learning content on the mobile device. Along with the research on iPad interventions in the classroom settings, Cochrane [30] also highlighted the necessity of a dedicated course assessment for technology assisted learning.

As mobile devices and underlying computing technology evolves, these advances can be utilized for the betterment of education structure and knowledge delivery. Many researchers agree that mobile-based learning facilitates improved interest and retention in students and has the potential to propel the overall manner in which we teach or learn. Personalization of the content, education beyond the classroom walls, and more emotional connection to the learning content can be provided by universal mobile technology. This content provision can be personalized with the help of several attributes. Personal profiling, individual responses, and cognitive load assessment are some of the attributes that can be utilized to present the profiled content to the learner. M-learning practices can be tailored to provide a rich personalized learning experience to serve students with various learning and research interests [137][138][139][140]. Ng [103] suggested personalized content on the mobile devices of learners. Even if a practically functioning system was never built, a conceptual architecture is presented to drive content personalization and hybrid learning. Mobile-based learning also aims to engage a massive user interest by improving learner engagement. Therefore, researchers have been trying to focus on the production of intriguing learning content in order to support the cause. The intentions of mobile-based learning go beyond the classroom. De Waard et Al. [37] tried to assess interest level in learners with the help of mobile technology. This research was conducted to support remote collaboration, synergy, active dialogue, and long-term retention. Mobile-based online courses (MobilMOOCS) are some of the most popular mobile-based learning platforms. De Waard et. Al predominantly used MobilMOOCS to study enhanced engagement using mobile devices in learners. With similar intentions of educating adults and including them in the stream of active learners, Slakovic and Savic [127] conducted a comprehensive survey of 347 adults living in Serbia in the age group of 60 to 75. The authors found that most of the adults were interested in computer science, art, and foreign language training. Results also revealed that that they desired long lasting education platforms. By understanding the usage patterns of the users and their smart devices, authors also concluded that adults in this age group could utilize mobile devices effectively and educate themselves efficiently with longer retention. Perez, von Isenburg, Yu, Tuttle and Adams [108] reported a significant increase in the utilization and satisfaction of online resources when medical trainees at Duke University were allowed to use the hospital distributed iPads. The frequency of visits to the most versatile medical databases, PubMed and DynaMed, increased significantly. This usage data was self-reported. Factors that hindered students from benefiting from the affordances of the mobile devices were the feasibility of carrying the device, internet connection, and accessibility of medical records content. Alamoud, Ganapathy, and McCarthy [8] provided evidence that the 7-inch tablet size was ideal for medical trainees and their daily lives on campus. This device size fits perfectly in the scrub pockets allowing easy content availability on the run. Therefore, the 7 inch mobile tablets can be viewed as ideal training devices for a large spectrum of learners.

An innovative system designed by Kalloo and Mohan [77] called MobileMath teaches mathematics to high school students in an innovative way. MobileMath uses alternative teaching practices with gamified content, and fun class activities. MobileMath has created a massive impact on students' overall mathematics performance. González et al. [58] designed a mobile-based physics learning system, which has proved to be effective on students' performance while learning physics. With this mobile-based learning system, students utilized mobile devices in laboratories as measurement devices, which opens up a massive opportunity to integrate mobile devices into laboratory settings. This can lead to the development of inexpensive yet efficient physics laboratories, which further research and provide valuable learning experiences for students.

The overall development of the learning content for any learner can follow either one or a combination of two carefully noted metaphors, which are game and cinematic experience [106]. The gaming metaphor engages the learners through the common elements associated with the gaming: such as competition, excitement, and instant gratification. The cinematic metaphor tries to convey the learning information through elements such as: narrations, reading content, and stories [155]. Staying parallel with a systematic and organized delivery of the content, it is imperative to provide the learner with the best learning and usage experience. This means that the user should not just receive the best usability by the device and the content but also the content should be desirable, credible, and pleasing [112][113]. This allows for a detailed user experience honeycomb-based inspection of the learning content [110]. Parsons, Ryu and Cranshaw [106] also stress the importance that the delivered content should not just be logically correct and strict to the metaphorical rules but it should also be conceivable and user-centered. They also presented with the design framework to understand the learner requirements, as well as design, develop, and test the mobile-based learning material to provide a better personalized learning experience.

Mobile-based learning has provided multiple examples of performance improvement. The success can be mapped on multiple dimensions. These dimensions are success in formal test results, improved retention, and increased involvement in the learning process. Cochrane [30] published some of the critical mobile-learning related factors such as course assessment, instructor involvement, and success of educational tools. Wang, Shen, Novak and Pan [157] reported a successful integration of m-learning practice for a massive scale English learning classroom. This success was reported as significantly increased involvement in the overall learning process.

From the literature review, it is evident that there is a lack of a systematic approach to understanding learning roadblocks and providing technology-based solutions for engineering students for learning STEM concepts. Addressing these shortcomings through technology assistance, specifically mobile-scaffolding, still lacks multiple important components such as - providing support for classroom content; additional instructor designed notes; efficient note making; and so on. Potential steps to provide a holistic solution for improved student engagement are conducting deep dive user research, developing appropriate learning content, testing for effectiveness, and understanding the attitudes of the students towards technology. Even though the efforts towards the development of an ecosystem for mobile-based education is rapidly advancing, these efforts are seen to be deviating from the basic principle of providing mobile-based educational support on primary learning content.

For the mobile-based learning systems to be effective, it is important to understand the educational structure and the needs of students. Therefore, a detailed study of educational structure and its taxonomy becomes important to identify exact technology integration points.

2.2 TAXONOMY OF EDUCATIONAL PRACTICES

The objectives of the educational practices are defined by Bloom [20], and Bloom et. al [22]. These objectives are arranged in the form of taxonomy. The development of this taxonomy facilitates a common language of learning goals between educators, curriculum designers, and administrators. These objectives form a common basis for the determination of educational goals, evaluation, and reporting. The traditional Bloom's educational taxonomy is defined in six different steps of learning. These steps are termed as (Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation). The definition of these levels is as follows:

Knowledge: In the knowledge level of Bloom's Taxonomy, questions are asked solely to test whether a student has gained specific information from the lesson.

Comprehension: The comprehension level of Bloom's Taxonomy has students go past simply recalling facts and instead has them understanding the information. With this level, they will be able to interpret the facts.

Application: In application questions, students have to actually apply, or use, the knowledge they have learned. They might be asked to solve a problem with the information they have gained in class being necessary to come up with a viable solution for a real-world problem.

Analysis: In the analysis level, students are expected to go beyond two previous levels, knowledge and application and actually come up with patterns that they can apply towards analyzing a real-world problem.

Synthesis: Within synthesis level, students are required to use the given facts to create new theories and make predictions according to these formed theories. They are expected to apply knowledge (learnt or concluded) from multiple subjects and logically synthesize this information to come up to a conclusion.

Evaluation: This is the top level of Bloom's Taxonomy of educational objectives. Here students are expected to assess the information related to a much larger real world problem involving multiple disciplines, and requires knowledge from multiple subjects learnt. Students are also expected to come to a conclusion such as the value, bias for the information, or form hypothesis about it [21][22][111].

Levels 1-3 (Knowledge, Comprehension and Application) in the taxonomy are called as Low-level learning skills and levels 4-6 are called as high-level learning skills. Felder and Brent [40], Felder and Silverman [44], Felder, Woods, Stice, and Rugarcia [46], Felder, and Brent [49] have shown that the general classroom teaching and evaluation is able to assess the effectiveness only up to the first three levels of the Bloom’s taxonomy of educational objectives. The other three levels: namely, analysis, synthesis, and evaluation are real world application dependent, require the demonstration of experience from the subject and duration of time for which the knowledge is showcased. These levels require a longer time for assessment and also the expertise to understand the subject’s performance output over a larger timeline. In order to pass any judgment about any practice for classroom based learning, the best possible marker on the effectiveness of the testing procedure is the test for students’ knowledge acquisition and retention test. The traditional Bloom’s taxonomy and the revised Bloom’s taxonomy both follow a pyramidal structure starting from the base knowledge to the evaluation level [21][22][51][53].

Krathwohl, Bloom, and Masia [88] found that most educational objectives can be placed into three major learning domains: cognitive, affective, and psychomotor. A major difference in the original and revised taxonomy with three leaning domains is that the original taxonomy has defined the learning abilities only for one (cognitive) domain. These domains are defined as follows:

Cognitive learning domain:

Bloom, Engelhart, Furst, Hill, and Krathwohl [22] defined the cognitive education domain as recalling or the recognition of knowledge and the development of intellectual abilities and skillsets. Cognitive domain represents the entire definition of Bloom's original taxonomy of educational objectives which is defined in the previous section.

Affective learning domain:

According to Kearney [79], affective learning is defined as the increasing internalization of positive attitudes and empathy towards content, subject matter, and teaching methodologies. Krathwohl, Bloom and Masia [88] and Anderson et. Al [10] and Rovai, Wighting, Baker, and Grooms [119] have shown that the affective learning domain deals with interests, opinions, emotions, attitudes, and values related to the educational practices, assisting technology, and overall learning process.

Psychomotor learning domain:

The outcome of this learning process is ultimately showcased when the acquired knowledge is transcribed into the motor skills or speed, dexterity, grace towards the application of skills [51][119][126].

In summary, the cognitive domain involves knowledge and the development of intellectual skills. Affective domain describes learning objectives that emphasize a feeling, tone, emotion, or a degree of acceptance or rejection. This domain includes the manner in which we deal with things emotionally such as feelings, values, appreciation, enthusiasms, motivations, and attitudes [148][149][150][151][152][153][154][163].

The affective education domain is essential in understanding how scaffolding intervention is acceptable in terms of performance enhancement and overall positive attitude of the students. Psychomotor domain describes the educational objectives related to the motor and physical coordination achieved by the learner through learning practices [10][21][22]. For classroom practices and traditional learning in confined time envelopes, it is very difficult to measure the objectives of the psychomotor domain. The action of integrating technology in the classroom environment has immediate measurable outcomes which can be measured in the cognitive and the affective domain of the educational objectives. The educational objectives are designed in order to define the methodologies of delivering the knowledge students in efficient ways. These objectives also provide critical benchmarking steps in order to form detailed assessment of the teaching methodologies [128][129].

2.3 LEARNING STYLES

Educational practices define the way in which the students interact in terms of exchanging knowledge. Educational practices not only determine the success of the knowledge transfer process but also determine the attitude and the values that become engrained in the students. The educational practices are generally distinguished between two categories: formal and informal. The description and differentiation between the two is as follows:

2.3.1 Formal Education Practices

The assignment of traditional teaching practices into the educational domain is termed as deductive teaching practices [40][41][43][44][45][156]. These teaching practices start with the concept and end in the application of the concept into real world problems. This is called deductive learning. The deductive learning practice typically begins with the introduction of the concept into the formal classroom setting. The instructor may introduce this concept to the students with the help of printed literature or textbooks. The concept may be in the form of a theorem or a principle printed in a textbook in relation to the subject being taught. This concept is then unfolded to the students with the help of theoretical proofs and derivations. The students then learn the theorem proofs by heart in order to further drive the development of the concept. The instructor then introduces some of the theory based problems in the form of homework, assignments, labs and projects which are based on the theorems. The students make the individual efforts to solve these problems. After these theory-based problems, students are introduced to the word problems which is one of the key challenges for the engineering students. Generally, in deductive learning practices, the application of the actual concept comes when the student is exposed to real world problem or when the student actually starts working in the industry which demands application of these learnt concepts in practice. These deductive teaching practices are in the category of 'Chalk and board' traditional teaching. These teaching practices are instructor centered [40][42][44][45][47][48]. The data from the first round of the user-centered research carried out with the engineering students at Wright State University unanimously confirms this problem, especially in the field of Mathematics. The word problems are designed for the students to comfortably implement their knowledge in the industry. However, when students are faced with these challenges in industry, it has proven to be one of the toughest areas for [5][6]. This problem arises due to the fact that the students are not familiar with the problem-solving environments and there is not enough practice for the students to have hands on knowledge about the problem based knowledge acquisition. When students are not able to make solid connections between word problems and real world hurdles, the entire teaching process becomes a loop.

In formal learning practices, students' performance is based on practice problems and the connection students can maintain between the theoretical and real world problems. There is very limited technology involvement in the classroom. Since the classes are instructor driven, there is very limited active communication between peers. Additional learning materials are provided by the instructor so students are instructor dependent in terms of gaining knowledge and additional practice. Deductive teaching may better promote short term retention of factual information [40][43][44][114][115][120]. The graduating students learned with the help of deductive teaching practices, and real world exposure. Due to the lack of development of underlying concepts, lack of training in necessary skills, and deficiency in technological exposure, engineering students often lose interest and opt to drop out of the engineering curriculum [16][17][59][60][61][156][162].

The following are the general properties of formal learning practices:

- Formal learning practices are teacher driven, teacher centered and teacher directed education practices. These education practices are traditional and are followed in most of the learning institutions by the educators with large classroom sizes.
- They are closed ended, allow for very less active discussions involving peers and the instructors.
- The formal learning practices are structured and follow the strict knowledge formation pattern.

- The process of knowledge transfer is strictly curriculum based and the context of learning is only limited to classroom level. Due to the sequential structure of these learning practices, there are few chances to come back into the curriculum or catch up with the class if a lecture is missed by the student.
- The knowledge transfer measurements are empirical and there is a little chance for holistic assessment of the knowledge transfer along with its effectiveness to be applied to the real-world problems. Students work on the problems and the revisions of the knowledge solitarily with generally asynchronous communication with instructors [71][161].

2.3.2 Informal Education Practices

The idea of informal learning practices begins with the idea of providing a holistic learning experience for students. Informal education practices are designed to transform teacher -centered learning to student-centered learning. Informal learning practices are focused on the development of students and their conceptual knowledge base [25][44][46][135]. Since informal learning practices are primarily focused on the development of students' ability to apply the gained knowledge, they are granted complete freedom to choose the schedule and resources they utilize during the learning period. Therefore, these learning practices allow for the integration of technology and its changing dynamics. Due to advancement in the internet and in handheld devices, reading practices and self-educating methods are constantly being reshaped. Informal teaching methods offer a solution to accommodate this reshaping of technology [92][137][140]. Informal learning practices follow the inductive way of transferring the knowledge. Inductive learning practices begin with the introduction of real-world problems. Students are allowed to struggle positively in order to build their knowledge base while solving problems. In order to build knowledge, students are allowed to use several different means. They can utilize different technologies, information sources, team collaborations, and group discussions. Multiple different models concerning instructional methodologies have been defined. The following is a highlight of different inductive teaching models, which are commonly employed:

Inquiry-based Instruction (Inquiry-based or challenge-based learning): Teaching begins with an introduction of the problem or a challenge. The instructor provides the content guided to answer that problem. Instructors work with the students as guides if the students find themselves struggling to find the answers. In this situation, the instructor provides the students with additional support with learning material.

Problem-based Learning: The focus is to address a problem as authentic, open ended, or not well defined. The students work in coordinated teams and instructor support is minimal. Students are pushed to learn new concepts in problem based learning.

Project-based Learning (Abbreviated as PBL) and Hybrid (problem/project based learning): Students are assigned some kind of project or design to build. In project based instruction, students are free to apply their previous knowledge to relevant projects.

Case-based Learning: Students examine case studies that involve the concepts and methods that the instructor needs to teach. Students work out problems involved in the case and compare those solutions with real world solutions.

Discovery Learning: Students are exposed to real world scenarios directly with minimal or no instructor support. They are observed in the process.

Just-In-time teaching: This method uses the technology support and just before the class begins, the instructor allows the student to answer a few questions and submit the answers electronically. The instructor responds in the same way and reveals the answers[40][42][43][47].

The following are the properties of the informal learning:

Informal learning practices follow unstructured and unsequenced methods of teaching and learning Informal learning practices are student centered and student focused. Knowledge transfer is generally not evaluated through a formal examination process but rather through the application of knowledge to real-world problems. Informal learning activities are non-assessed and unevaluated, but they are reflected through the students' ability to solve the problem. Informal learning practices are generally non-curriculum based and are outside of school context. These learning practices are designed in order to take the learning experience beyond the walls of a regular classroom. Since these learning practices are student-centered, these methods set students free for thinking through and apply their knowledge and abilities to perform certain tasks. Due to their unstructured nature, there are several unintended outcomes. Since the informal learning practices are learner led and learner directed, they are open ended and allow for students to gather as much knowledge as they wish. Along with just the primary learning concept, students learn several other concepts. One of the major benefits of informal learning practices is that the student is not alone. He or she is always engaged in social interactions, collaborating on a team, or are working across different platforms. While informal learning practices are learner led, the supervisory control is always with the teacher who administers the entire learning process [62][71][161].

One of the branches of informal learning practices is active learning, which focuses on the introduction of learning practices, which generate students' rapport with the learning content. The goals and properties of active learning are explained in the section below.

2.3.2.1 Active Learning

Generally, active learning is defined as the learning activity that engages student in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing [42][43][45][50][115][162]. Active learning in turn supports activity that aids in student understanding, and student engagement in the overall learning of concepts. The underlying hypothesis of this dissertation examines form factors based technology and how it aids in learning basic science and mathematics concepts for engineering curriculum. Bonwell and Eison [23] carefully studied the literature, upon examination they concluded through evidence based studies that the practical implementations of active learning could ignite significant learning interests among students. Hake [62] has shown through his study of about 6500 students over 62 courses, that interactive and engaging learning activities help students improve performance more so than traditional learning methodologies. These activities are seen as means for better development of analytical and conceptual problem solving skills. A detailed summary of active learning practices from Bonwell and Eison [23] have shown that the introduction of active learning practice applications, even in small amounts, can increase the learning capabilities and the keenness towards learning materials by multitudes. The core elements of active learning are:

1. Introducing meaningful activities into traditional lecture.
2. Promoting student engagement.

Some of the suggested strategies for active learning are detailed by Meyers and Jones [99]. These strategies involve activities such as various small-group exercises, simulations, and case studies that can be blended with] technology and human resources found outside the classroom. Felder [48], Felder and Soloman [45], Felder, Woods, Stice and Rugarcia [46], and Stice, Felder, Woods, and Rugarcia [131] have stressed strongly the use of technology inside and outside the classroom to promote student keenness and curiosity in understanding the content. This integration can also promote positive attitude building and empathy towards the learning content. Through the process of building empathy for the content, the students can relate more to the learning content and feel immersed in it. This content therefore can compel the students to learn and later apply the same concepts in solving real world problems [114][115].

Student engagement profile has a parallel existence in the active learning domain. Student engagement in the learning process is essential for collective success of the learning practice as well as the development of positive attitudes in students [75]. The development of positive attitude decides the success of technology integration processes.

From literature review, we can conclude that the informal learning practices can help improve student performance. Informal learning practices promote the inter-student interactions. These learning practices encourage non-traditional, assisted learning practices. Hence, we need to identify solution that would support such informal learning practices, without disrupting the classroom learning practices. With recent advances and availability of mobile devices, they can act as assisted learning practices. Although completely replacing the formal education structure with the informal one may not be possible but a significant improvement in the students' performances can be achieved through integrating mobile-based assistants in already existing formal education practices.

3 RESEARCH PHASE 1 - CONCEPT IDENTIFICATION

In order to begin with the development of the mobile-based augmented learning platform, we needed to understand the challenges that students face when learning basic concepts in engineering. In nationwide engineering schools, difficult topics or concepts correlate directly to dropout rates from engineering degree programs. to gain a better understanding of what engineering topics were difficult for students, we designed a two-staged user-centered data collection in order to collect detailed responses from the students about difficult subjects in engineering degree programs. The collection of the data consisted of forming a list of tough engineering topics and the underlying concepts collected from the first stage of the user-centered research. The second set of difficult engineering topics were collected from the students in engineering degree programs. Also, a list of peripheral things around the students that may result in making these concepts difficult to understand. The details of these two phases are described as follows:

3.1 PHASE 1A RESEARCH

The first phase of the user-centered research was designed to collect responses from students to identify potential difficult engineering topics and underlying concepts. In order to form a comprehensive list of the most difficult subjects in the engineering degree programs. to help isolate the most difficult concepts that can be used for providing students with additional learning support.

We interviewed 37 individual participants. The population consisted of engineering students who had been in the engineering degree program for more than two years. The interviewees were selected from a random mixed pool of genders, races, ethnicities, and diverse engineering majors. The interview questions were designed to probe the interviewees for feedback on specific tough subjects in Science, Technology, Engineering and Mathematics (STEM). The results were compiled from the interview outcomes. These interviews obtained some of the common topics the education domain students mentioned as some of the most difficult to comprehend. Students were given open-ended questionnaires and were asked to comment generously on different topics encountered in engineering. Almost all of the students reported calculus as one of the most difficult subjects in Mathematics. As the level of calculus got advanced, students faced a huge number of roadblocks. The origin of these roadblocks was due to the weaker concept base from the basic calculus class. Eventually, 85% of the students lost their interest when they reached calculus III from calculus II and from calculus I. The students' struggle continued in differential equations and matrix algebra subjects. In the science streams, similar trends are seen in advanced subjects in Physics, Chemistry and Biology. The results of this phase of user-centered research are as follows:

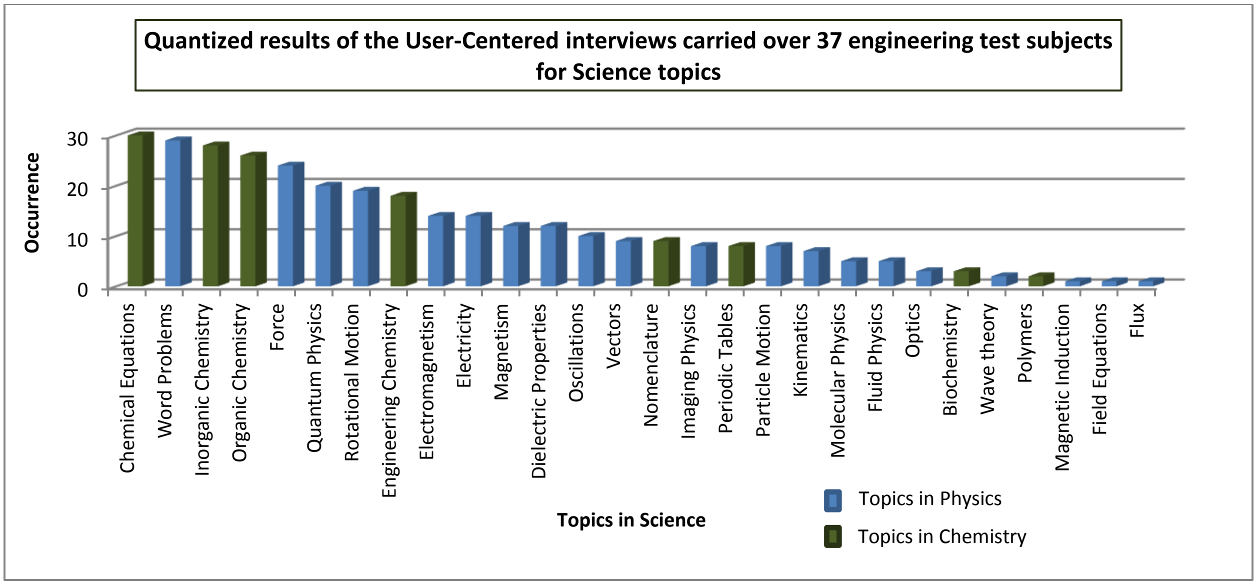

Figure 3.1: Phase 1a: Primary User-Centered research to collect the difficult engineering topics in the science education domain

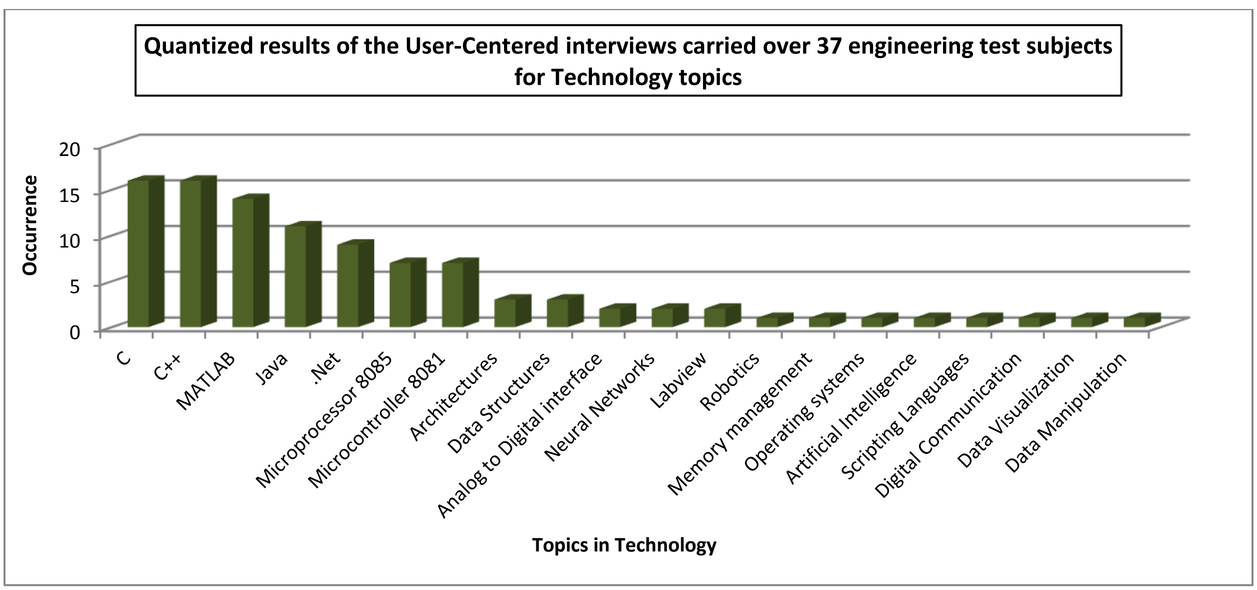

Figure 3.2: Phase 1a: Primary User-Centered research to collect the difficult engineering topics in the technology education domain

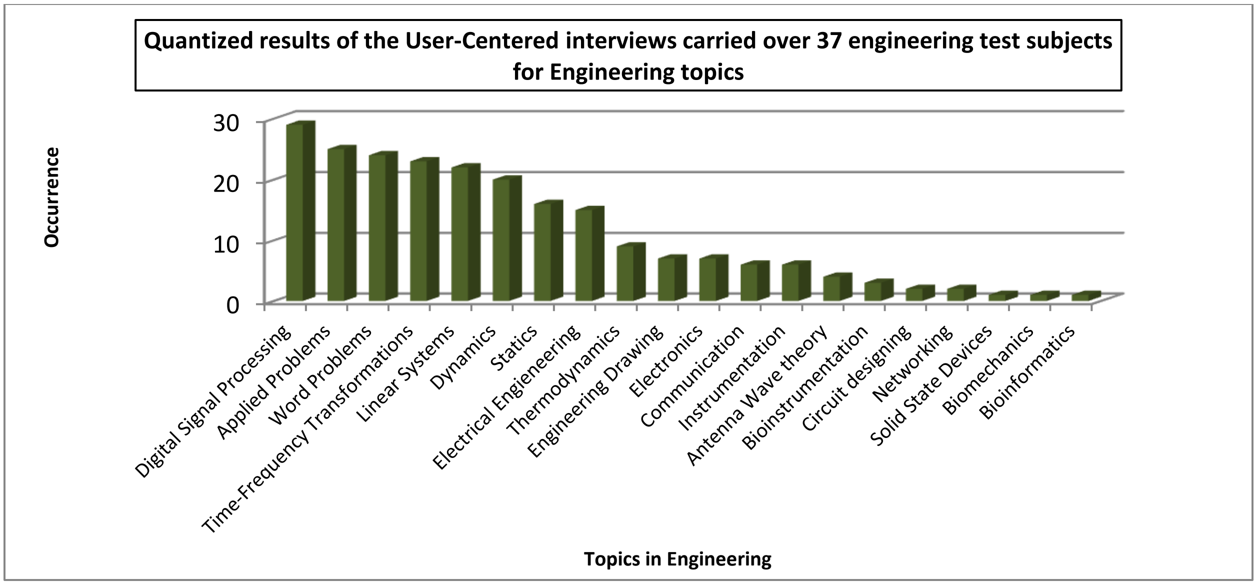

Figure 3.3: Phase 1a: Primary User-Centered research to collect the difficult engineering topics in the engineering education domain

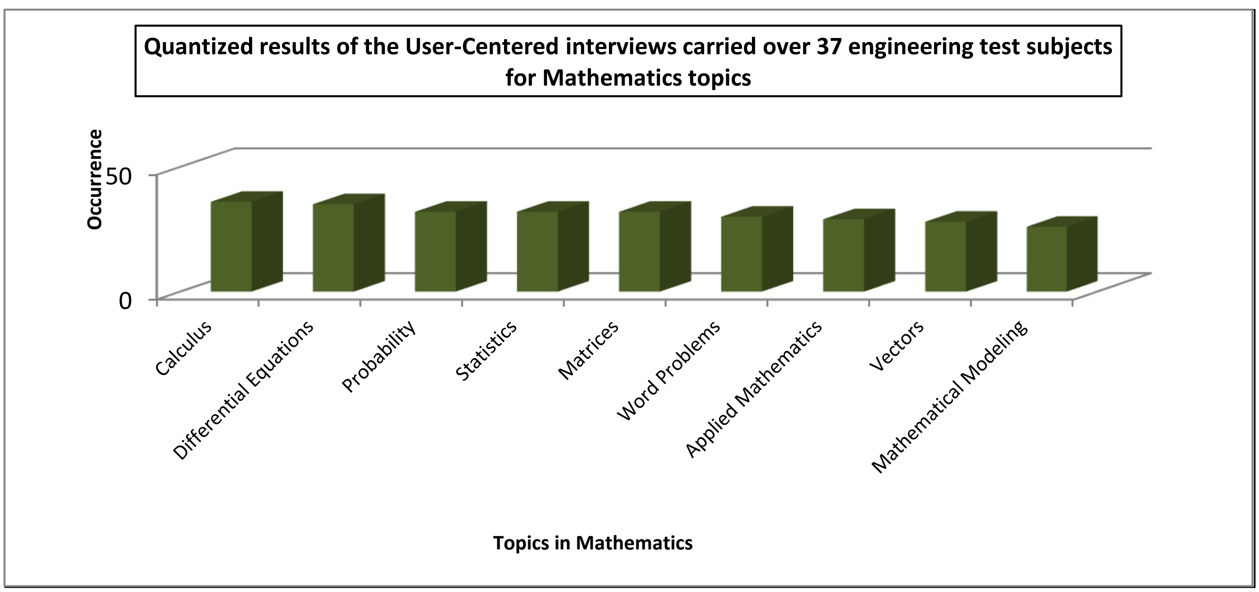

Figure 3.4: Phase 1a: Primary User-Centered research to collect the difficult engineering topics in the mathematics education domain

The direct implication of this research was the design of phase 1B of the user-centered data collection research.

Table 3.1: Salient outcomes of the phase 1a research.

Physics	**Mathematics**
Newton’s Laws of Motion	Limits
Friction	Derivatives
Quantum Physics	Differential Equations
Imaging Physics	Probability

3.2 PHASE 1B RESEARCH

This phase of the user-centered research was designed to deep-dive into the sub-topics and individual concepts of from the list of the tough subjects that students reported in phase 1A of the user-centered research. This step of the research was designed to observe some of the possible reasons for these reported roadblocks and how can they be answered individually. This user-centered research was also designed to understand possible methods and solutions from the students’ perspective. A survey template was designed and developed at the Interactions Design and Modeling lab at Wright State University in order to collect this data. In order to form this list of tough concepts, we carried out a thorough inspection of the engineering topics taught in various engineering majors. All the individual engineering departments in the College of Engineering and Computer Science at Wright

State University extended special collaborative efforts in order to compile the list of tough subjects and subtopics. Through this inspection, we were able to form a detailed list of these individual engineering topics. Along with the subjects' list, we also formed a more distilled list of individual concepts taught in these subjects. For the cross departmental courses such as physics, mathematics and statistics courses, we performed a thorough investigation of these courses through the individual department websites. These course websites clearly detailed the subtopics and the program schedules for the courses which were reported by the students. The results of phase 1 research were also incorporated in this list in order to get the granular details about any breadth course that students might enroll for in their degree program. In order to finalize the survey template, we carried out a round of small informal interviews with the office staff of the individual engineering departments to gather the subject insights. Through this set of informal interviews, we were also able to gather a detailed list of underlying concepts involved in the individual subjects. This detailed list of concepts and subtopics was presented to the students along with a list of possible improvements students would like to implement in the education system while learning these different subjects. The survey allowed the students to comment in detail about the reasons why a particular engineering topic was difficult to learn.

The student responses were primarily collected through web-based survey. An advertisement about this web-based survey was done through the engineering school- email sent through the administrative office. The advertisement of the surveys was also done through word of mouth publicity. The following figures show the results of the phase 1b research.

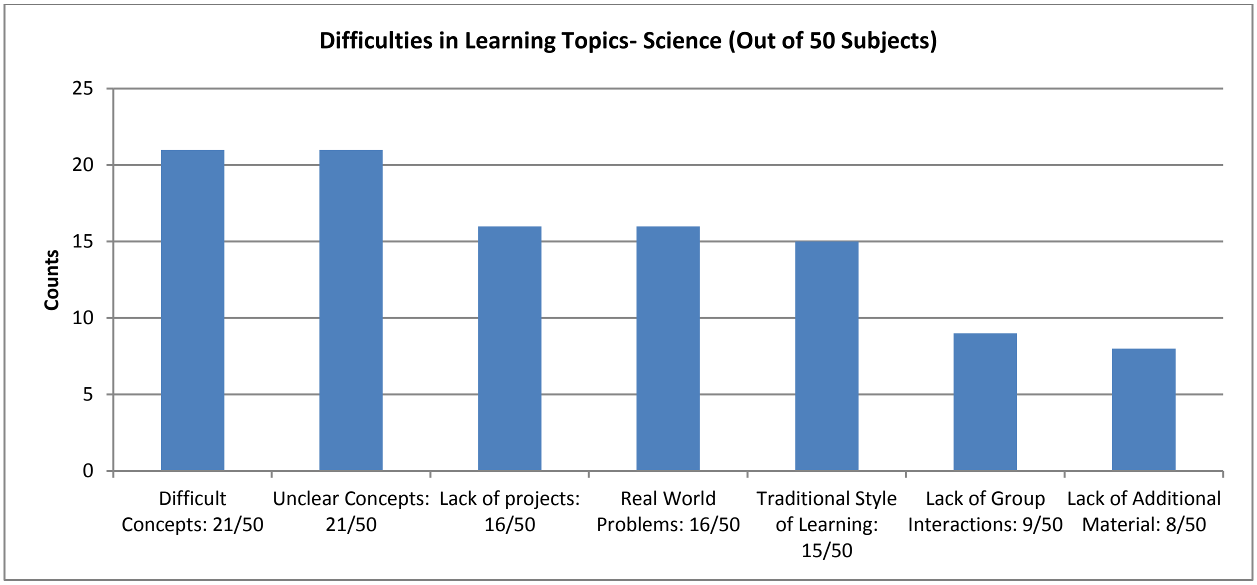

Figure 3.5: Phase 2: Deep Dive-user-centered research to collect the difficulties in the Science education domain

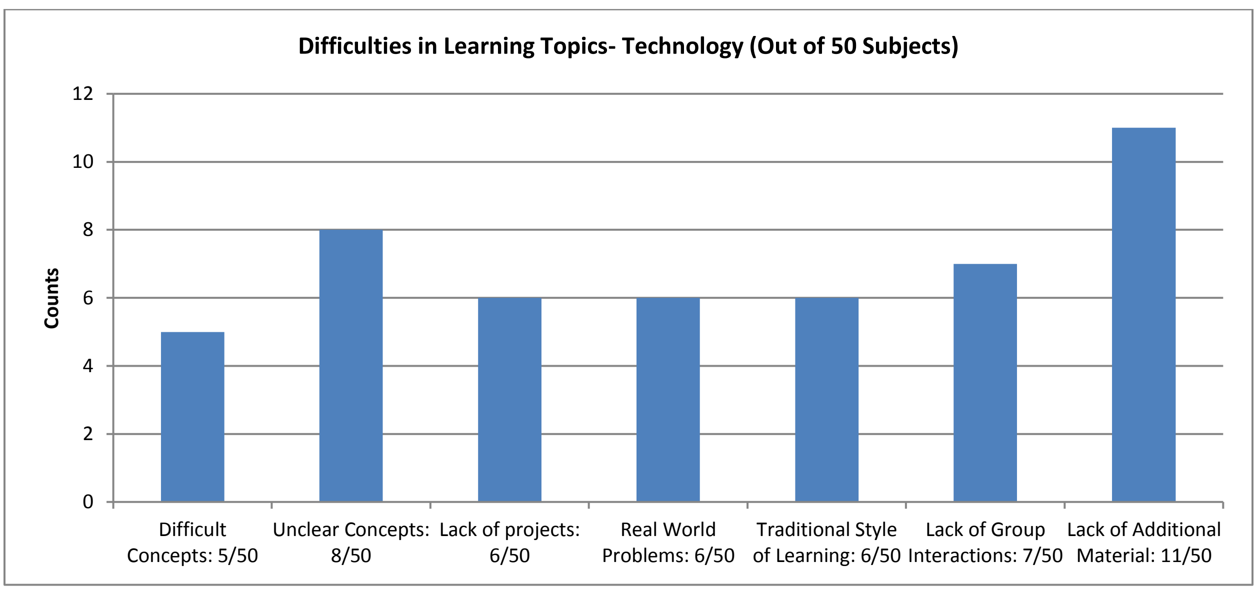

Figure 3.6: Phase 2: Deep Dive user-centered research to collect the difficulties in the Technology education domain

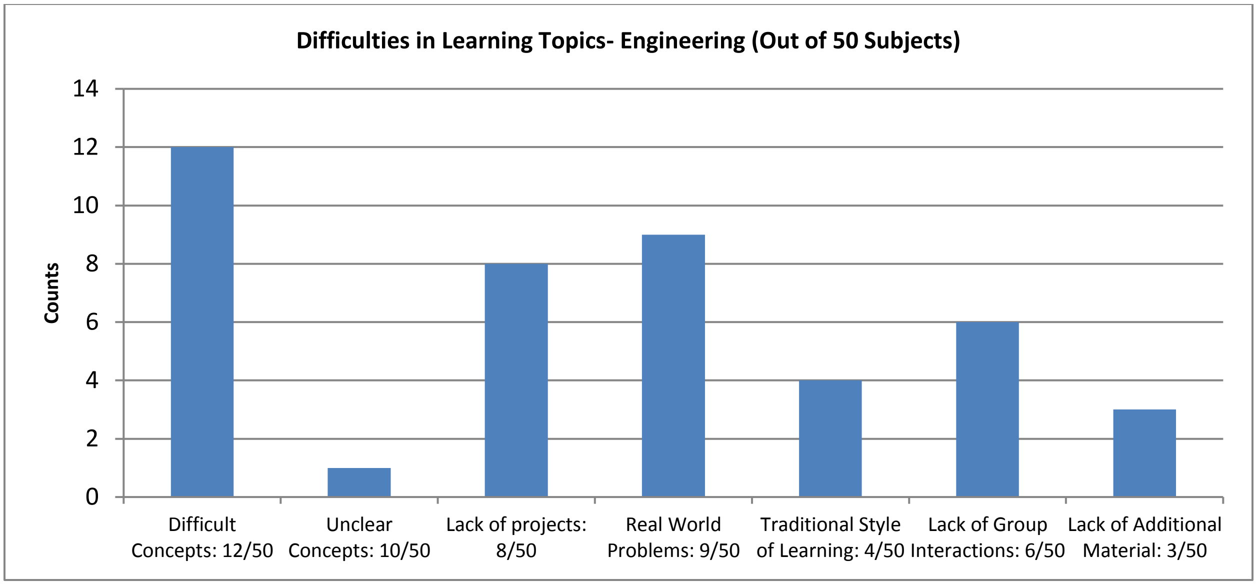

Figure 3.7: Phase 2: Deep Dive user-centered research to collect the difficulties in the Engineering education domain

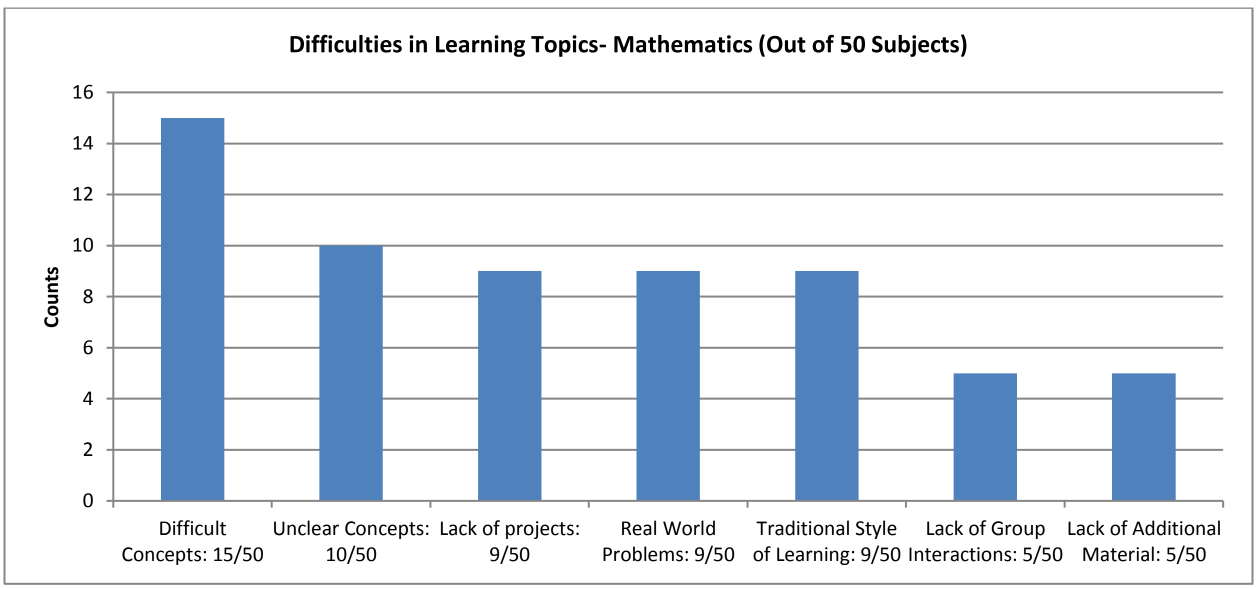

Figure 3.8: Phase 2: Deep Dive user-centered research to collect the difficulties in the Mathematics education domain

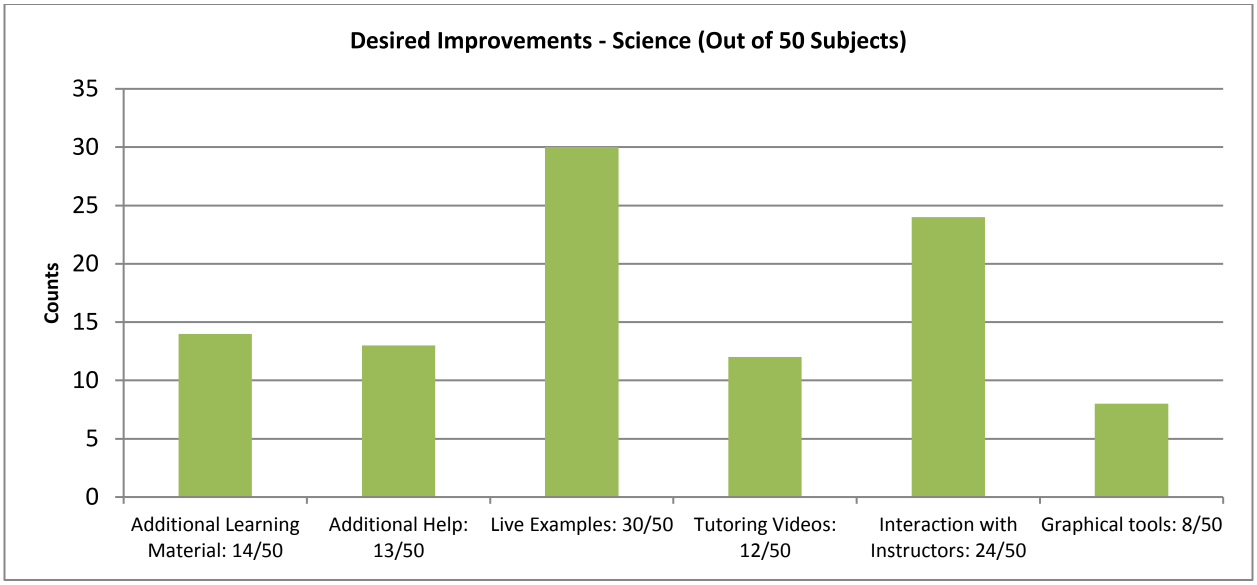

Figure 3.9: Phase 2: Deep Dive-user-centered research to understand the desired improvements in the Science education domain

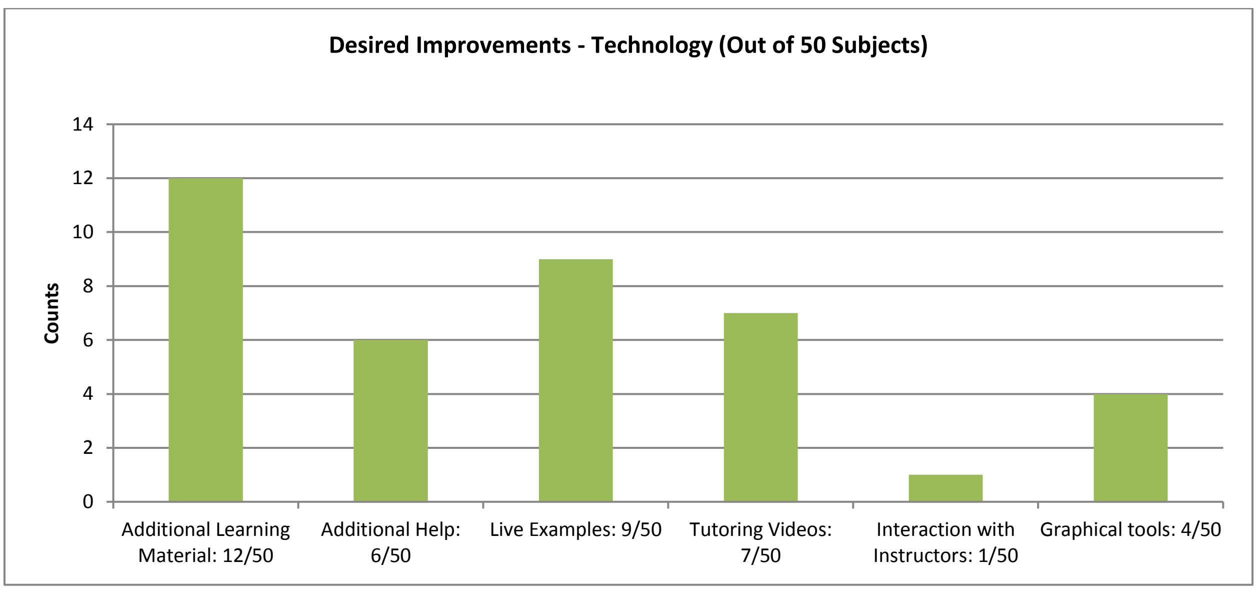

Figure 3.10: Phase 2: Deep Dive-user-centered research to understand the desired improvements in the Technology education domain

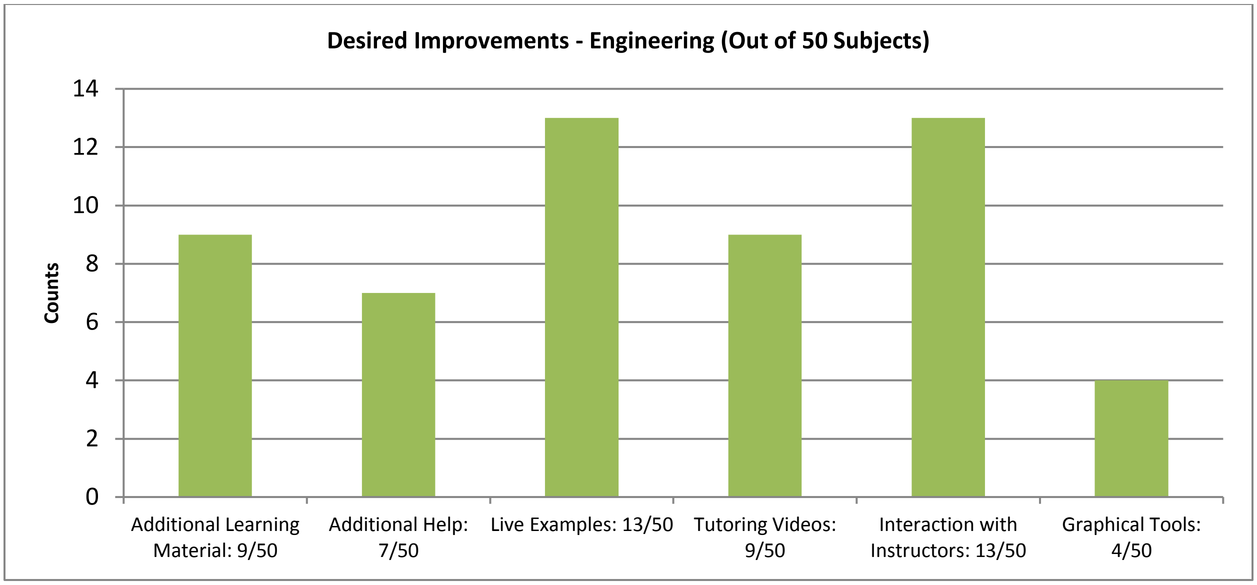

Figure 3.11: Phase 2: Deep Dive-user-centered research to understand the desired improvements in the Engineering education domain

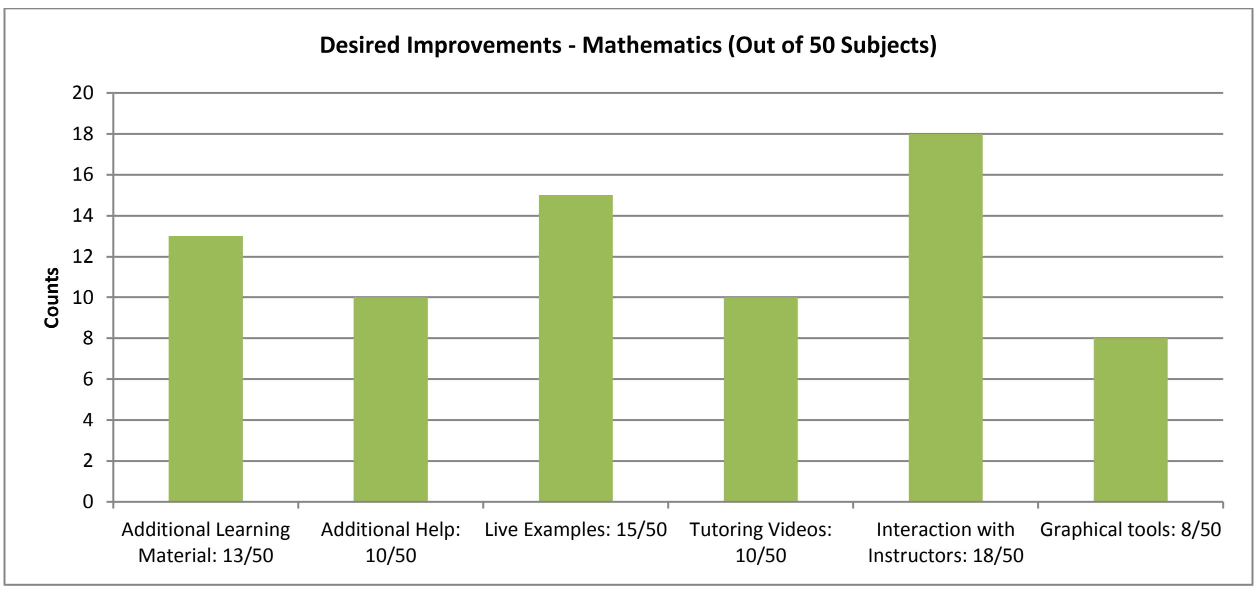

Figure 3.12: Phase 2: Deep Dive-user-centered research to understand the desired improvements in the Mathematics education domain

Table 3.2: Salient outcomes of the phase 1b research.

Top difficulties in learning	**Desired Improvements**
Traditional learning styles	Additional learning material
Lack of additional material	Interaction with instructors
Difficult concepts	Graphing tools
Real world problems	Learning through examples

From the findings, it was evident that most of the students faced similar difficulties learning the basic STEM subjects essential to engineering. The top three concepts extracted from this research for mobile-based assistant development and testing were:

1. Calculus
2. Friction
3. Newton's Laws of Motion

The difficulties related to the essential knowledge material were abstract, difficult and unclear concepts. Graduating students faced difficult times in handling applied problems and projects in the industries. Therefore, students demanded working with the data pertaining to such problems and felt a strong need of inclusion of real world problems in the educational curriculum. Due to the abstract concepts, fast paced classes and traditional teaching styles, students found it extremely challenging adjusting to the pace of the class. Despite having keen interest in the class material, many students experience a tough time learning the subject. As an outcome of the deep dive user-centered research, from the data we gathered, we can conclude that, in learning the subjects, students showed keen inclination towards learning with real life examples. We executed this with the help of videos, tutorials, and graphical tools; which were one of the most desirable tools in learning about specific equations according to students [5][6]. From this research, it is clear that the students are seeking for a technology-based assistant that a) supports the classroom learning, b) provides non-disruptive, in-context support for concept learning, c) employs a blended approach with the classroom learning material, and d) it should be easy to use with minimal training required to use it. Along with these properties, this learning assistant should also allow easy navigation through the hosted learning material and it should also be seamlessly integrated with the classroom environment. The need findings from this research led to the development of a detailed analysis of existing mobile-based learning apps with respect to the features and a development of a landscape analysis dashboard to identify gaps.

4 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

4.1 RESEARCH OBJECTIVES

The research objectives of this dissertation are as follows:

1. Develop a mobile augmented learning system to help students learn the basic engineering concepts in mathematics and physics supporting in-class learning.
2. Assess the performance of the effectiveness of the mobile technology integration in learning basic engineering concepts.
3. Develop taxonomy of design guidelines to facilitate designing of supportive content for engineering students on mobile devices.

Design and develop User Centered Technology Acceptance Model (UCTAM) that allows validation of the design and can predict behavioral intention of the students who intend to utilize mobile technology as a technology assistant.

4.2 RESEARCH QUESTIONS

The following are the key research questions for the above stated research objectives.

R1:

Is integrating mobile technology effective in assisting students with knowledge acquisition?

R2:

Which form factor is the most suitable?

- Mobility
- Portability
- Content Presentation
- Ease of handling

R3:

How accurately can the User Centered Technology Acceptance Model predict the user intention to use the technology?

Next chapter presents a detailed overview of the mobile learning assistant developed for this study.

5 MOBILE-BASED AUGMENTED LEARNING SYSTEM DESIGN

The immediate outcome of the user research was the development of a mobile-based augmented learning assistant that can help engineering students overcome some of the challenges that were identified in Phase 1 (Chapter 3) of this research project. Another salient outcome of this pilot research was the list of features, which were used for the comparative analysis for several market apps for their usefulness in the educational settings. From this research, the list of features was obtained, which was used for the comparative analysis of the available education supportive apps. This list of features is as follows:

1. Detailed User Analysis
2. In-Context Access
3. Blended Approach
4. Ease of Use
5. Planned Content
6. Seamless Integration
7. Ease of Navigation
8. Non-disruptive
9. Formal Testing Support

Following table shows the comparative landscape analysis of some of the leading education apps - Khan Academy, LearnUpon, Configio, AktivMind, SimpleMind.

Table 5.1: Landscape Analysis – Learning Applications

Feature	Khan Academy	LearnUpon	Configio	ActivMind	SimpleMind
Detailed User Analysis	✓	✓	✓	✓	✓
In Context Access	✓	✓	✓	✓	✓
Blended approach	×	×	×	×	×
Ease of use	✓	✓	✓	✓	✓
Planned content	✓	✓	×	×	×
Seamless integration	×	×	×	×	×
Ease of navigation	✓	×	×	×	×
Non-disruptive	×	×	×	×	×
Formal testing support	✓	✓	✓	✓	✓

Another intention behind the development of this system was to introduce portability of the learning content and to take the whole learning experience beyond the walls of general classroom settings. The engineering concepts for the mobile-based augmented learning content were chosen from the list of roadblocks received from the students in the user-centered research phase. The top 3 concepts were picked in order to design the content and conduct testing over this style of content presentation. These concepts were - Limits and derivatives, Newton's laws of motion, and Friction. Students also reported that it could have been a real positive impact if they were provided with additional help with these concepts.

The development platform selected for the mobile-based augmented learning system was Android®. The intention behind the development of the mobile-based augmented learning assistant was to extract most of the affordances offered by these devices. The assistant program was designed to support almost all the diverse learning styles from the in-class content-based learners to repetitive visual learners. This mobile-based augmented learning system was designed to complement the in-class learning and enhance the learning capability through this technology intervention. One of the major intentions behind the development of mobile-based augmented learning system was that this assistant should not be disruptive and it should complement the in-class learning. The mobile devices acted as augmented devices that could display the same learning content as taught in the classes but it gave multiple interaction modalities for students to utilize the technology. Mobile devices allowed for multiple natural interactions which not only allowed for students to search for appropriate learning content through browsers but also enabled actions such as note-making, viewing graphs, viewing additional learning material, and so on. The design and additional learning cues are explained in section 5.1.

5.1 SYSTEM DESIGN

The system is designed based on usability guidelines and by identifying the interaction modalities that can be presented for content consumption. Since the device primarily presents classroom learning content, Figure 5.1 shows an example of how classroom-based PowerPoint content is presented on the mobile device. These slides can be scrolled with natural left to right and right to left swipes. Through the flexibility aspect of the content, we have designed an ability to access any slide of the overall class any time on the mobile device. Figure 5.2 illustrates how this flexible navigation is achieved.

5.1.1 Accessing any other slide from any slide in the lecture stack

From any slide in the stack; any other slide can be accessed. The tray which contains all the slide links can be found on the left hand top side of the slides.

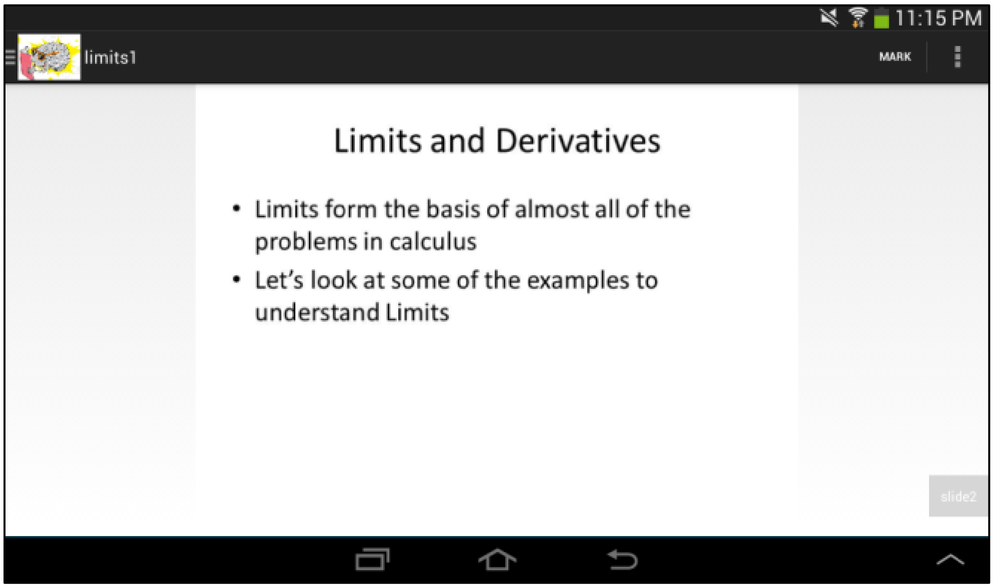

Figure 5.1: Primary Content Screen

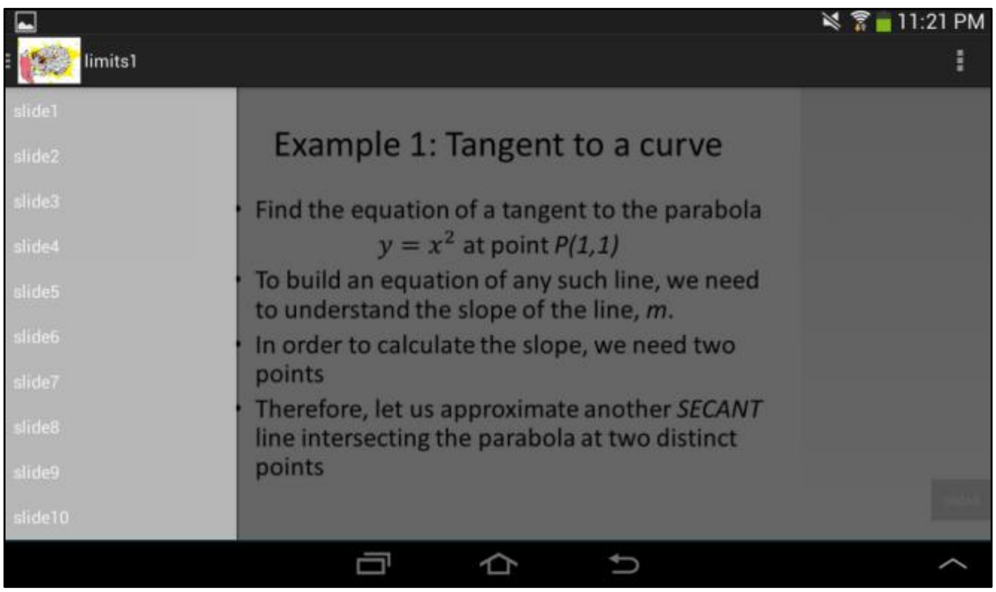

Figure 5.2: Screen showing the open tray with links to all the slides

It is a common practice to take down notes during the class sessions. Mobile augmented learning system allows students to take notes in two different ways. There is a provision of taking notes on every slide. Due to these choices, note taking on any slide is fast and easy. Following illustration demonstrates two different ways in which note making is possible.

5.1.2 **Note Making**

This feature allows students to take notes either by typing or writing on screen. On long clicking on the screen, a default icon that appears is note making which is shown in figure 5.3. Figure 5.4 and figure 5.5 demonstrate how typed notes can be taken and saved.

Figure 5.3: Typed notes icon

The process to use typed notes is as follows:

1. Additional notes allow for taking the additional typed notes on a slide.
2. These notes are like ‘sticky notes’ and stay attached to the individual slide.
3. The notes are saved on the individual slides even after the slides are rolled up or back.
4. There is no need to specially save the notes. The notes are saved in real time as the user types them.

Long clicking on the Primary content screen (Figure 5.4), shows additional information options. The notepad icon displays the notepad as follows:

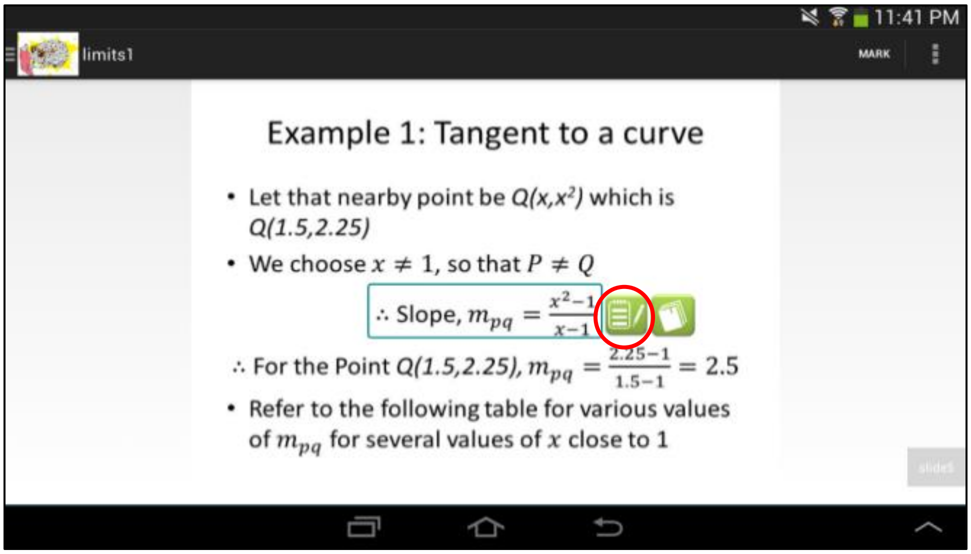

Figure 5.4: Additional options showing notepad

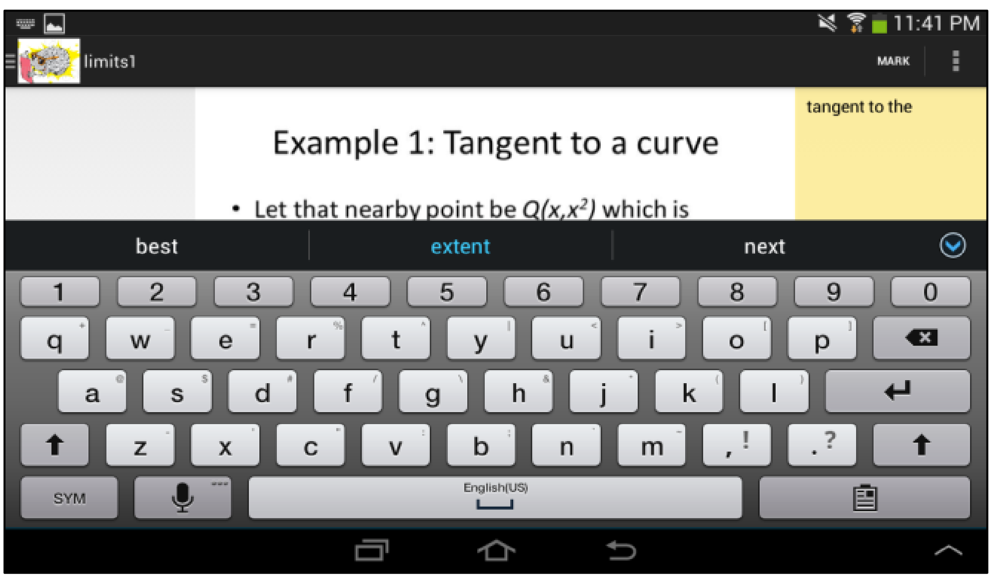

Figure 5.5: Typing notes on the slide

Second way of note taking is by marking. Following illustration demonstrates how note taking by writing on the mobile device screen can be taken and saved. Figure 5.6

shows the icon with which note taking by writing on the tablet can be imitated. Figure 5.7 and figure 5.8 demonstrate the process of writing notes on the mobile screen and saving these notes with the current slide the student is on.

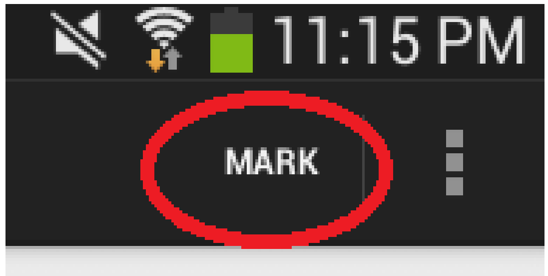

Figure 5.6: Marked notes icon

Process to use marked notes is as follows:

1. To allow the users to take the instantaneous notes right on the slides, click on the option called 'Mark'. This button is located on the top right side of the primary content slide.
2. This opens up a virtual canvas allowing free hand drawing/writing over the slides.
3. When clicked on 'Save', the image of the canvas along with the slide on the background is saved with the slide.
4. Multiple such hand-written notes can be saved for a particular slide.
5. To close the marking tool, click the system back button to close the tool, get back to the primary content slide and see the slide image with marked notes on the right-hand side.

From the primary content screen, click the option 'Mark' to start writing/drawing on the slide. A small vanishing message appears which says 'Draw Now'. Writing is possible from edge to edge of the screen. When clicked ‘save’, image of the written note is saved with the slide.

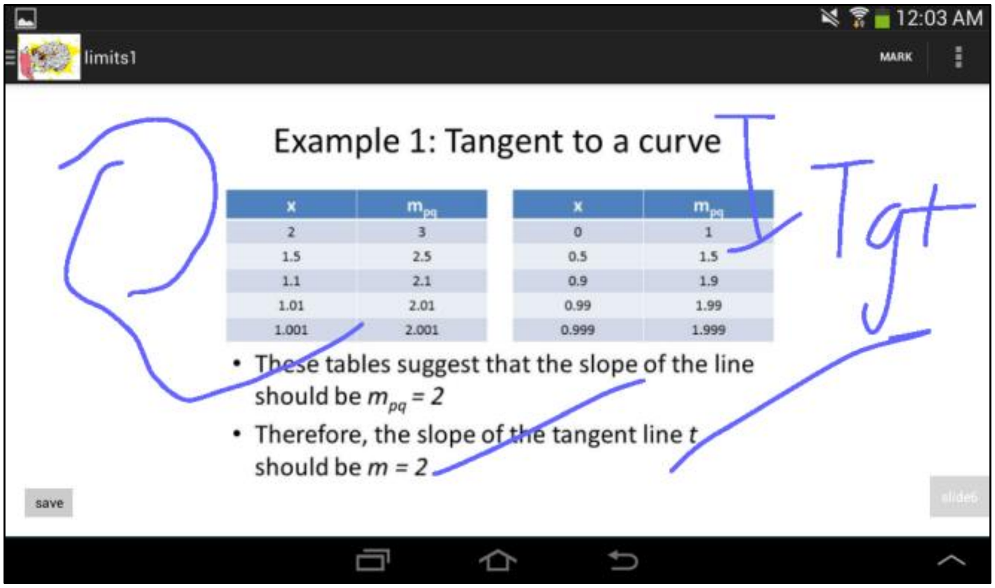

Figure 5.7: Taking notes on the slides after clicking ‘Mark’. When clicked on ‘Save’, these notes are saved along with the slides. The saved notes can be seen in the following image

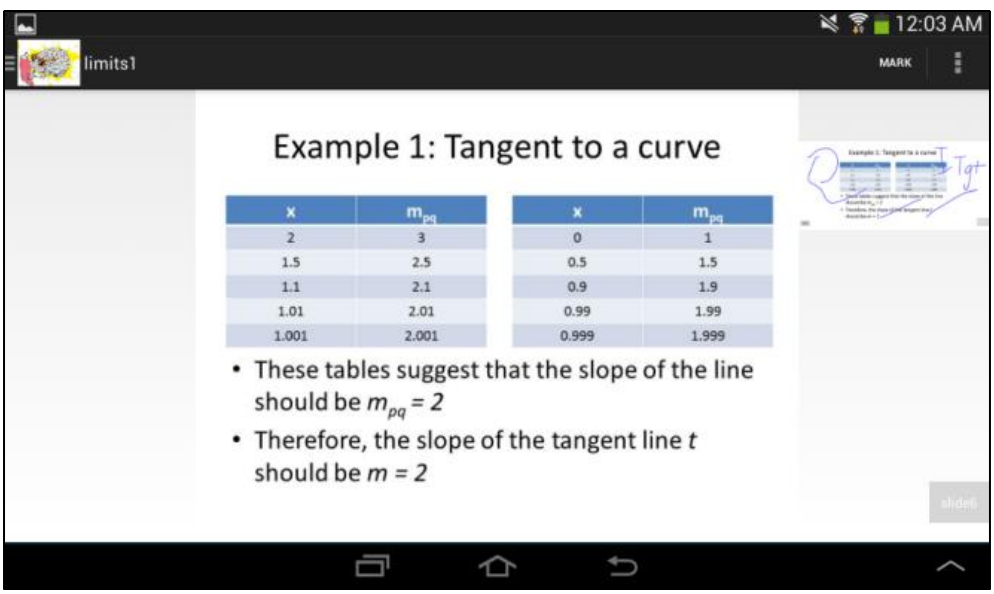

Figure 5.8: Saved notes along with the original slide

5.1.3 **Additional Learning Notes Provided by the Instructors**

Instructors often provide external notes to the students with illustrations and/or examples. The additional notes are not universal and are available for select keywords. This presence of the additional notes is denoted by the icon and the description mentioned below. Additional notes are like extra solved problems and illustrations. These notes are not available on all of the slides. They are available on select slides. Figure 5.9 shows the icon with which these notes can be accessed. Figure 5.10 and figure 5.11 demonstrate the process through which the additional notes can be accessed.

Figure 5.9: Additional content in the form of notes icon

Process to use additional content in the form of notes is as follows:

1 When the additional content notes are accessed, the primary content slides shrink in size to the left side top corner allowing full view of the slide content to the user.

2 The notes are not editable. They are provided to support the primary learning content.

3 To close the notes, click the system back button to close the notes and get back to the primary content slide.

Additional content notes can be accessed in the same way as the other additional content, by long clicking on the primary content slide.

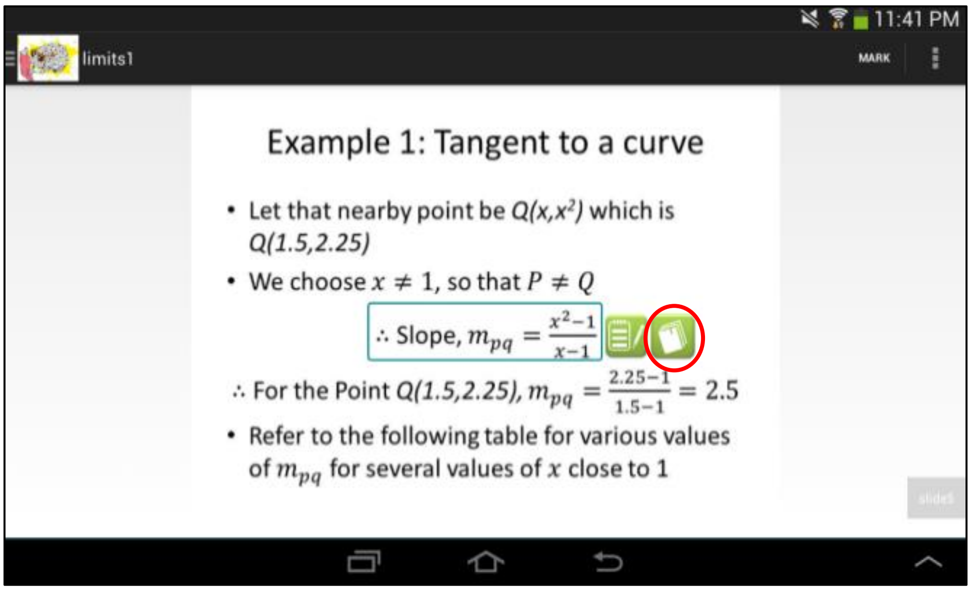

Figure 5.10: Additional options showing additional notes

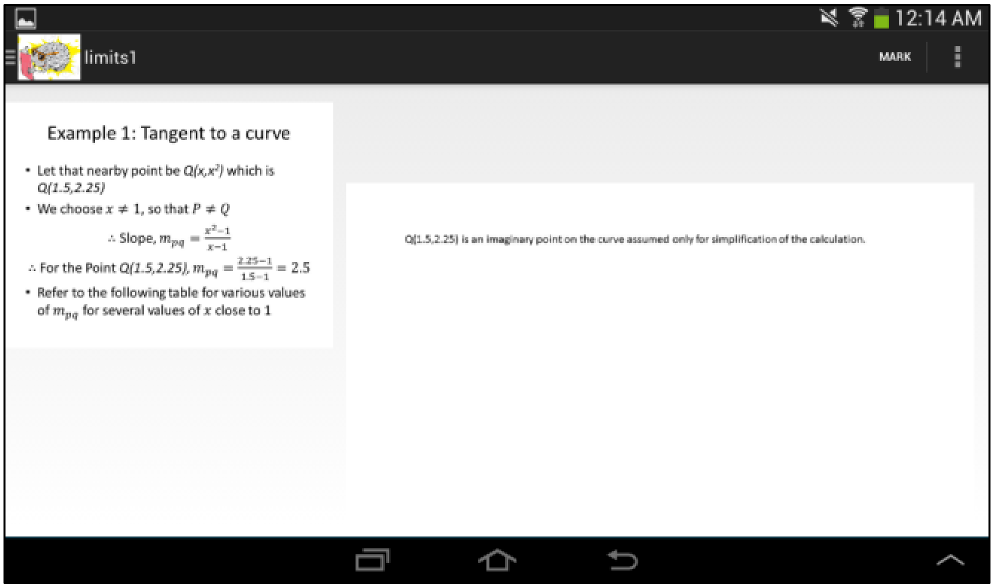

Figure 5.11: Additional notes shown with the primary content slide minimized in the left top corner.

5.1.4 **Interactive Graphs**

As mathematics content designers, we believed that it is very important to visualize the behavior of the functions. Therefore, to enable the students to understand the nature of the functions for learning the concepts of mathematics, visualization of the functions and their graphs has been included in the mobile-based augmented learning assistant. Interactive graphs are available only in and for the mathematics lectures. Interactive graphs are also available on select slides. The graphs can be accessed from the same workflow as accessing other additional learning materials. Figure 5.12 shows the icon with which the interactive graphs can be accessed. Figure 5.13, figure 5.14, and figure 5.15 demonstrate how the feature of interactive graphs can be accessed and used.

Figure 5.12: Interactive Graphs Icon

Process to use interactive graphs is as follows:

1. When the graph is accessed, the scale of the graph can easily be adjusted with simple pinch and zoom. This interaction allows the students to understand how the function is exactly behaving in general and at any point of interest.
2. In the top left hand side of the graph window, all the graphs which are part of the lecture are populated. This is done through a dropdown which opens up the tray with all the equations populated in the list.
3. Other equations can be plotted with the help of text entry box provided to the students in the right top corner. Here, the functions which are outside the set of equations provided can be written and the plotted.
4. To close the graph, click the system back button to close the graph and get back to the primary content slide.

Interactive graphs can be accessed from the primary content slides by long clicking on the primary content slide. The graphs can be zoomed in or out using pinch and zoom interaction. The additional graphs from the lecture stack can be accessed from the dropdown on the left-hand side top corner. Any additional graph can be plotted by typing the equation in the ‘Draw graph’ text box.

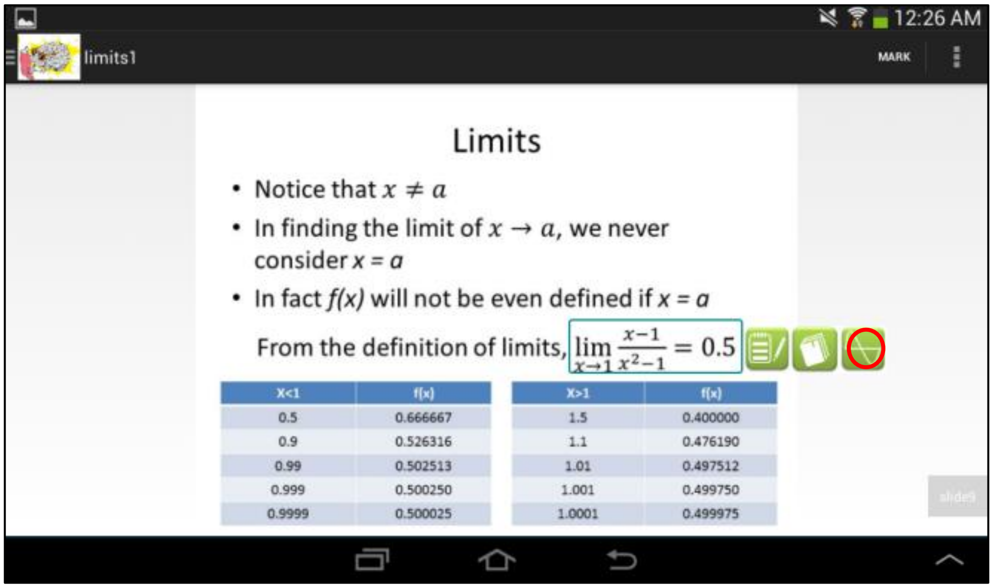

Figure 5.13: Additional learning materials showing the interactive graphs

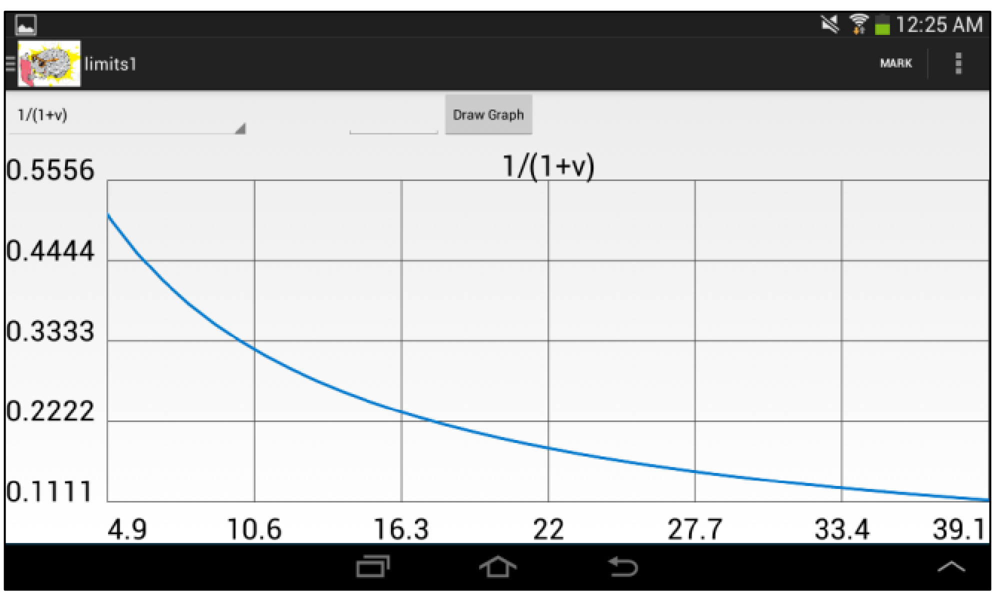

Figure 5.14: Interactive graph with pinch and zoom ability

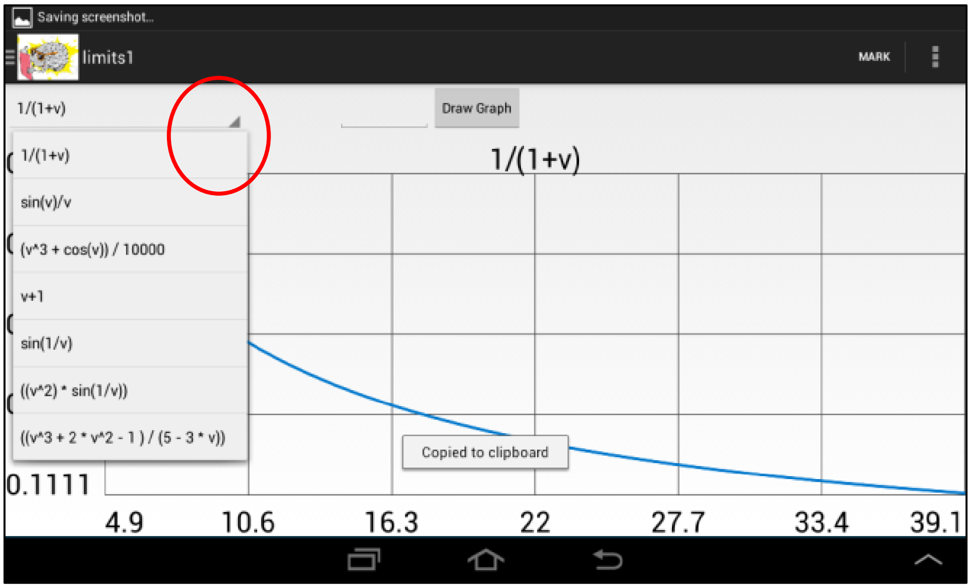

Figure 5.15: Dropdown with prepopulated list of graphs and textbox on right to write the equation to plot the graph

5.1.5 **Additional Videos**

Along with the class material, it is important to teach the visual learners with the help of additional videos. These videos allow the students to spend more time on the concept to be learnt. Videos are integrated within the learning content, which allows students to learn the concepts with a different modality over the same form factor. Additional videos are imported from ‘Khan academy’ and ‘Youtube’. These videos are available on select slides. They can be accessed in the same way as all other additional information content. Figure 5.16 shows the icon which allows the students to access additional videos. Figure 5.17 and figure 5.18 demonstrate how additional videos are accessed with the primary learning content.

Figure 5.16: Accessing Additional Videos Icon

Process to use additional videos is as follows:

1 When the additional content notes are accessed, the primary content slides shrink in size to the left side top corner allowing full view of the slide content to the user.

2 The right-hand side of the screen is utilized to display and play the video window.

3 The videos cannot be deleted. The videos cannot be edited. The videos positions can be controlled with the help of video timeline. Play-bar for the video can be accessed by tapping on the video and controls such as play, pause, rewind and fast forward for the video can be accessed.

4 To close the video, click the system back button to close the video and get back to the primary content slide.

Additional assisting videos can be accessed in the same way as the other additional content, by long clicking on the primary content slide. When the video option is selected, the primary content slide gets shrunk to the left side corner giving user the full look of the primary learning content along with the additional video. The video controls such as the timeline bar, play/pause, rewind and fast forward can be accessed by clicking on the video.

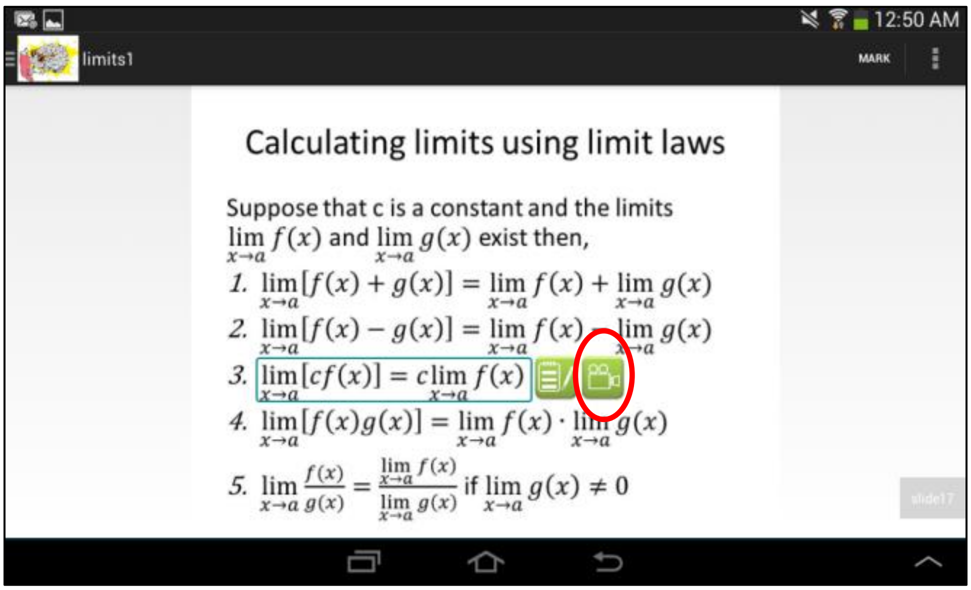

Fig 5.17: Additional learning materials showing the additional videos

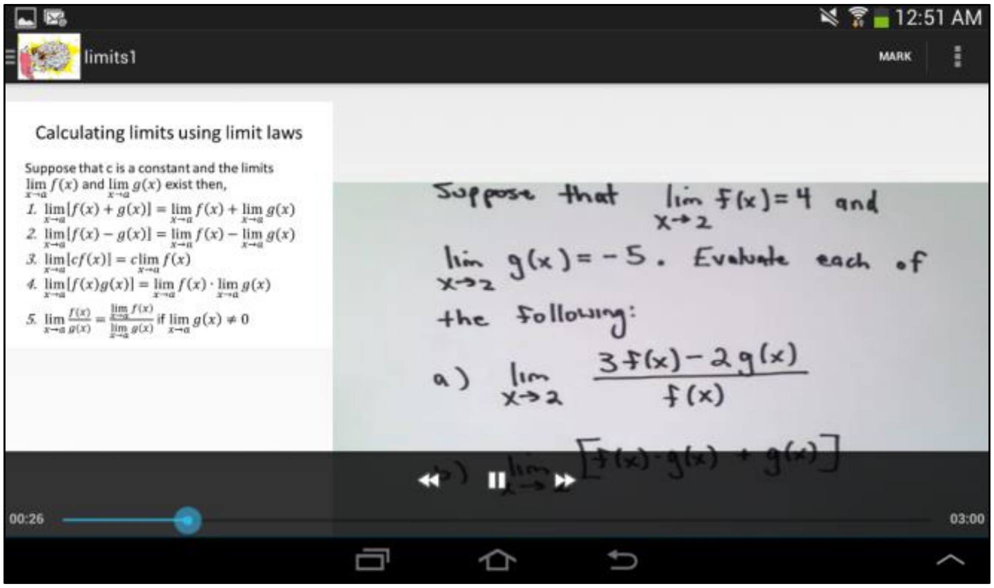

Fig 5.18: Additional learning videos with the primary content slide minimized in the left top corner. Video controls are seen in the image, and these controls appear on the click over the video

5.2 HEURISTIC EVALUATION

Heuristic evaluation was conducted by eight human factors experts in the field on the mobile learning system. These experts were mostly connected with Wright State University with a mix of students, professors and professionals working in the industry. The goal of this heuristic evaluation process is to come up with the iterating guidelines for the design improvement. The heuristics were also guided to improve the workflows and overall user experience (UX). These experts were recruited from the Wright State University and industry contacts. Each expert was given a detailed overview of the entire learning content, was taught every individual concept and they were actively encouraged to use the mobile-based augmented learning assistant. All of these experts were given a post-exposure questionnaire to describe their experience with the individual learning assisting cues. This questionnaire was developed at the Interactions Design and Modeling lab at Wright State University. These questionnaires were specifically targeted to answer the overall experience of all the components of the learning assistant based on the UX honeycomb. The concept of the UX honeycomb is developed by Morville [102]. Every individual feature of any product can be analyzed from the usability, usefulness, desirability, credibility, findability, accessibility and valuability with the help of UX honeycomb analysis. Likewise, every learning assistant cue is analyzed in detail on the UX honeycomb scale. The initial heuristic evaluation yielded the following results:

The description of the individual feature and the results of the detailed heuristic evaluation are as follows:

Content:

The content of the concepts was verified with the individual subject matter experts (Mathematics and Physics subject instructors at Wright State University). The content was developed with the help of respective course textbooks.

Heuristics results:

The content has proved to be authentic, verified and easy to understand.

Navigation

Slides can easily be navigated with the help of easy navigation menu. Content on any slide can be accessed with one-click navigation. This navigation is accessed by clicking.

Heuristics results:

This navigation menu makes the content access intuitive. The users do not have to slide one after the other.

Note Taking

This feature allows students to type notes on their tablet devices to save them with the respective primary learning content.

Heuristics results:

Students do not lose their orientation because the notes can either be written on the slide with just one button click or can be typed by selecting the notes option on long click. The note taking is very efficient and adds value to the entire learning experience.

Additional Notes

Heuristics results:

Additional notes provide the additional insights to the important keywords and add ease into the overall learning. From the detailed heuristic evaluation of the additional notes options included with the learning material, we found that since the notes have been provided by the educators, these notes added a tremendous credibility.

Interactive Graphs

Heuristics results:

The inclusion of the interactive graphs is one of the most useful tools to be introduced in mobile-based mathematics learning. All the test participants found the most use to it while solving limits for the continuous functions needing factorization and simplification. The included tool also allows for the students to type their equations of choice and plot them to view the behavior of the individual function. This custom equation plotting feature is also extremely desirable for the students.

Additional Videos

Heuristics results:

Additional videos have proved to be definitely desirable but do not show an extreme importance as some of the other features. This feature is primarily useful for learning outside the class. Though the videos are the integral part of the primary content, it is accessed and consumed by the students to try to understand the concept with deeper insights.

As shown in table 5.2, the mobile-based augmented learning system addresses the gaps identified in the comparative analysis.

Table 5.2: Landscape Analysis – Learning Applications with mobile augmented learning system

Feature	Khan Academy	LearnUpon	Configio	Activ Mind	Simple Mind	Mobile augmented learning system
Detailed User Analysis	✓	✓	✓	✓	✓	✓
In Context Access	✓	✓	✓	✓	✓	✓
Blended approach	×	×	×	×	×	✓
Ease of use	✓	✓	✓	✓	✓	✓
Planned content	✓	✓	×	×	×	✓
Seamless integratio n	×	×	×	×	×	✓
Ease of navigatio n	✓	×	×	×	×	✓
Non-disruptive	×	×	×	×	×	✓
Formal testing support	✓	✓	✓	✓	✓	×

6 DESIGN OF EXPERIMENT

In order to test the effectiveness of the mobile-based augmented learning system, an experiment was designed to assess any statistically significant difference in the performance of students learning with the technology, and students learning without the help of technology.

6.1 METHODS

The experiment conducted was a mixed factor design with independent variables as 1) type of engineering concepts – Math and Science; 2) type of learning - with/without mobile-based augmented learning system; and 3) type of user. The dependent variable was the user performance through formal tests.

6.1.1 Independent Variables

Type of Engineering Concept: In order to test the effectiveness of the system we designed the system for the top concept that was challenging for the students within engineering for Math and Science. We chose two types of concepts from Math and Science as they present different interaction needs with the system. These concepts were isolated from an engineering school wide study conducted by Abhyankar and Ganapathy as concepts were limits, Newton's laws of motion, and Friction [5][6]. These concepts were divided into four separate classes. From the user-centered research, the top three most difficult concepts were divided into 4 classes which were selected in order to provide assistance to students with the help of mobile devices. We developed the learning material for these topics with the help of respective professors teaching these concepts from the mathematics and physics department. A balanced experimental design was initiated with the development of four classes with these 3 concepts. Class material of Limits was split in 2 classes due to the length of the classes.

Type of Learning: This variable was to understand the use of the mobile-based augmented learning system. Participants were tested with technology and without technology as an augmented learning system.

1. **Type of User**: The type of test subjects for this study were divided into 3 groups. We wanted to study the need for mobile-based augmented learning system within the life-long learning concept of engineering education. The three user groups consisted of – undergraduate students, recent college graduates who graduated from the engineering degree programs for not more than 2 years; students graduated from the undergraduate engineering degree program for more than 2 years. A total of 276 test participants were tested. Not all the participants returned the test results and the ones who did not return the test responses, were removed from the analysis. These participants however were useful in collecting post-test data on the overall use of mobile devices and learning assistants. The total recruitment for this experiment was conducted from the pool of students affiliated with the College of Engineering and Computer Science at Wright State University. The total number of students who responded to the formal tests through this experiment was 119.Group 1: The first group of students consisted of 38 undergraduate students who were either new to the exposure of these concepts or have learnt these basic concepts not more than 4 years back. This cohort of the students is selected in order to provide a detailed insight about the technology to be implemented. This cohort is one of the most crucial groups of students under test.

One of the primary reasons to focus on the performance of this group is that; these are the students who have a fresh exposure to regular classroom learning for the concepts under test. Therefore, these students are considered to be important regarding providing feedback on the mobile-based technology intervention under testing. The GPA for this group ranged between 2.5-3.5. This GPA group was selected based on literature review from previous studies by Klingbeil; and Klingbeil and Bourne; and National Center for Education Statistics [28][82][83]. Referring to works of and Klingbeil and Bourne; and National Center for Education Statistics, a good education standing was granted to the students who maintained a high school GPA of 2.3 and up [28][83].

2. The second group of students was formed by 43 recent college graduates from the engineering program who have been graduated for less than 2 years. These were the students who either had just started working in the industry after graduation or were continuing their education in masters' degree programs. These are the students who most definitely require quick concept refreshes and these students are always looking for better and quicker avenues to learn. The only concern these students have is that they are not willing to invest immense amount of time in refreshing these concepts which they have already acquired and may have retained some pieces of the information.

3. The third group of students was formed by 38 college graduates from the undergraduate engineering degree program who had been graduates for more than two years. These student participants were senior masters' students, students in engineering PhD programs, or alumni who had been graduates of the

undergraduate degree programs for more than 2 years. Occasionally when working in the industry, people need to revisit some of already learnt content just to give these concepts a refresh.
The need to refresh concepts is very seldom. This concept refresh is very specifically tailored to problems they are trying to address in either their careers or specific research. The intended time investment is extremely minimal with the goal to receive the best refresh of the concept. Thus, people representing this group are looking for accelerated knowledge acquisition and retention methods. Multimodal learning and technology-based learning are some of the most desired modes of concept refreshing for these participants.

The entire population of the student participants is a good representation of mix of races, ethnicities and nationalities and GPA levels. Therefore, the test population is a good representation of students from all different levels of cultures, beliefs and intelligence levels of the entire society.

The description of the testing factors, procedures and the overall experimentation setup is as follows:

6.2 TEST PROCEDURE DESCRIPTION

The tests were conducted at the Interactions Design and Modeling lab in Russ Engineering Center in Wright State University. For every testing session, we conducted a group testing session where we limited the group size to 4 or 6. The reason to conduct testing in group sessions is to observe real students' interactions in the classroom. The tests were conducted in a laboratory environment in order to control for non-necessary interactions such as: chatting, longer group discussions, and so on. The tests were conducted with an even number of students, so that a balanced experimental design could be achieved. For the test assignment, half of the students used a mobile device and the other half of the students did not use a mobile device. Four different classes with 2 math concepts and 2 physics concepts were taught for 25 minutes each. Concepts of mathematics were divided in two classes. The condition on the mathematics classes is such that the second class of the limits must follow the first limits class. In order to randomize the experiment, the assignment of the treatment of the classes to the students is completely randomized. there were 10 possible assignments that could be administered to each student group.

The following are combinations of the science and mathematics assignments that were administered to the student participants.

Let S1 = Concept of Newton’s laws of motion

S2 = Concept of Friction

M1 = First class of Limits and Derivatives

M2 = Second class of Limits and Derivatives

Table 6.1: Treatment assignment for the groups

Treatment Number	Concept 1	Concept 2	Concept 3	Concept 4
1	M1	M2	S1	S2
2	M1	M2	S2	S1
3	S1	M1	M2	S2
4	S2	M1	M2	S1
5	S1	S2	M1	M2
6	S2	S1	M1	M2
7	M1	S1	S2	M2
8	M1	S2	S1	M2
9	S1	M1	S2	M2
10	S2	M1	S1	M2

A completely randomized treatment was assigned to any test group coming in for the testing. Since there were 42 testing sessions, every treatment was randomly administered 4 times and treatment number 6 and 8 were assigned 5 times each.

6.3 TESTING PROCEDURE

Picture 6.1: Study Picture 1

Picture 6.2: Study Picture 2

When the participants arrived, they entered the testing room, where they were arranged randomly for treatment from table 1. This treatment allowed us to control the order in which the participants were exposed to the concepts under the test. All test participants were consenting adults. After assigning treatment for the group, all participants were allowed to read the detailed study description and procedure before signing the consent form and participating in the test. The remuneration allocated for each test participant was $20.00. Each participant was provided with the incentive information at the end of the test. They were also given clear directions that the participation was voluntary. Every participant was asked to enter their university or international GPA. Participants were given a practice session on the mobile application. They were asked to use it as long as they wanted to feel comfortable interacting with the device. It was not a timed session, however typically participants did not take more than ten minutes during the practice session. This could be probably because all of them are familiar with mobile device interactions. Participants were listed randomly as they arrived and the first participant in that randomly arranged list was assigned the first concept in the treatments from Table 6.1. This concept was taught to the first participant with the help of mobile technology. The following concept was taught to the participant without the use of any technology. The same procedure was repeated for all test participants. For example, if participant number 1 was assigned to learn the concept of "Newton's laws of motion" with the help of mobile technology, the same participant was required to learn the concept of "Friction" without the help of technology. Similarly, if the participants learned the first half of "Limits and Derivatives" without the help of technology, then they were required to learn the second half with the help of technology. Proper care was taken while assigning the test treatments.

Both concepts from either science or mathematics were not taught only with mobile technology or only without the help of mobile technology.

Students were seated randomly. Each session had students form different groups and the test groups were balanced. During the teaching period, these concepts were taught with the help of a projected screen on the wall. The learning content was the same as the content hosted on mobile devices. The content on mobile devices had some additional learning material such as instantaneous note taking, graphing tools, embedded videos, and additional lecture notes. Participants learning with the help of technology got a chance to view the learning material twice, take notes on the device, visualize mathematical functions' behaviors, and view the additional instructor notes. Measures were taken to make sure every concept was taught in the detail and the same detail to teach every other concept was maintained for all the participant groups under test. Only the principal investigator was involved in conducting the teaching sessions. We also ensured a uniform teaching style for every concept. This included very specific pointers about the slides, quotes, sharing experiences, and so on. Each test session were recorded for only first 30 minutes to understand how the user was interacting with the mobile devices. Students using mobile devices were encouraged to use their devices to take notes as they were learning.

After teaching the concepts, students were given a documentation packet which included a questionnaire to investigate students attitudes towards this type of learning assistant technology. This packet also included one formal test for all covered concepts. The questionnaire is covered in detail in Appendix A. Tests for the concepts are described in Appendix B. Test participants were allowed to take the test and solve the questionnaire in one week’s time. The allowed time to solve the test and the questionnaire was a week.

Test results were compiled at the Interactions Design and Modeling Lab. The data from questionnaires was compiled with the help of Microsoft Excel and it was tested with the Chronbach Alpha validity test. The formal tests from the test participants were graded and the results were compiled. The graded test records were recorded with the participant name and the technology treatment received by the students for every concept. Therefore, for every group, the formal test results for the technology treatment were directly comparable to the formal test results without the technology treatment.

7 RESULTS

7.1 EFFECT OF MOBILE-BASED AUGMENTED LEARNING SYSTEM ON ENGINEERING CONCEPT

The goal of this analysis is to address the research objective related to understanding effectiveness mobile augmented system for engineering subjects. Therefore, in order to prove the effectiveness of mobile-technology integration in the educational practices, exactly half of the students were taught mathematics with technology and other half without the use of mobile technology.

For the student participants, we wanted to understand the effectiveness of the technology integration for multiple engineering concepts such as physics and mathematics. This analysis can convey the information about the appropriate impact of technology integration as seen by the significant improvement in the overall formal test results.

Independent variables:

1. Use of technology
2. Engineering Concept - Mathematics, Physics

Dependent variable: Student performance

μ_{PW} = Mean test results of the test participants learning physics with technology.

μ_{PWO} = Mean test results of the test participants learning physics without technology.

μ_{MW} = Mean test results of the test participants learning mathematics with technology.

μ_{MWO} = Mean test results of the test participants learning mathematics without technology.

Hypotheses for physics:

H_{0P}: There is no significant difference in the mean test scores of the students learning physics with and without technology.

$$\therefore \mu_{PW} = \mu_{PWO}$$

Hypotheses for mathematics:

H_{0M}: There is no significant difference in the mean test scores of the students learning mathematics with and without technology.

$$\therefore \mu_{MW} = \mu_{MWO}$$

Table 7.1: Comparison of means of test scores of physics and mathematics for all participant groups learning with and without technology

	Engineering Concepts			
	Physics		Mathematics	
	P Value = 0.0001		P Value = 0.0005	
	Mean = 64.08 With Tech	Mean = 48.45 Without Tech	Mean = 66.19 With Tech	Mean = 55.87 Without Tech
User Groups	Use of Technology			
	With Technology	Without Technology	With Technology	Without Technology
Group 1	P Value = 0.001		P Value = 0.148	
	Mean = 71.34	Mean = 52.39	Mean = 68.92	Mean = 61.18
Group 2	P Value = 0.015		P Value = 0.124	
	Mean = 55.95	Mean = 42.93	Mean = 62.49	Mean = 54.84
Group 3	P Value = 0.002		P Value = 0.002	
	Mean = 66.03	Mean = 51.03	Mean = 67.66	Mean = 51.74

Table 7.2: Comparison of means of test scores of physics and mathematics for the participant groups learning with and without technology

Engineering Concept	**Result**
Physics	P Value = 0.0001 t_0^*= 5.036 Degrees of Freedom (Calculated) = 236 $t_{\alpha/2,DF}$ = 1.97 Mean test score with technology = 64.08 > Mean test score without technology = 48.45 Since, $\|t_0^*\|> t_{\alpha/2,DF}$, We reject null hypothesis. There is a significant difference in the mean test scores of the students learning physics with and without the help of mobile devices.
Mathematics	P Value = 0.0005 t_0^*= 3.51 Degrees of Freedom (Calculated) = 233 $t_{\alpha/2,DF}$ = 1.97

	Mean test score with technology = 66.19 > Mean test score without technology = 55.87 Since, $\|t_0^*\|> t_{\alpha/2,DF}$, We reject null hypothesis. There is a significant difference in the mean test scores of the students learning mathematics with and without the help of mobile devices.

Significant differences in the mean test scores of the participants using the mobile technology and not using the mobile technology confirms the hypothesis that the mobile technology integration in the educational practices is effective and at a grander schema, the effects can be seen clearly. Therefore, the information presentation on mobile platform is helpful for the knowledge acquisition.

7.2 EFFECT OF MOBILE-BASED AUGMENTED LEARNING SYSTEM ON STUDENT GROUPS

This section will discuss the results based on the analysis related to the effect of mobile-based augmented learning system on student groups.

Independent variables:

1. Use of technology
2. Subject (Mathematics/Physics)
3. Student Groups -
   i. Group 1 = Undergraduate students

ii. Group 2 = Group of recent college graduates graduated for not more than 2 years.

iii. Group 3 = Group of recent college graduates graduated for more than 2 years.

Dependent variable: Student performance

μ_{PWG1} = Mean test results of the test participants from group 1 learning physics with technology.

μ_{PWOG1} = Mean test results of the test participants from group 1 learning physics without technology.

μ_{MWG1} = Mean test results of the test participants from group 1 learning mathematics with technology.

μ_{MWOG1} = Mean test results of the test participants from group 1 learning mathematics without technology.

μ_{PWG2} = Mean test results of the test participants from group 2 learning physics with technology.

μ_{PWOG2} = Mean test results of the test participants from group 2 learning physics without technology.

μ_{MWG2} = Mean test results of the test participants from group 2 learning mathematics with technology.

μ_{MWO2} = Mean test results of the test participants from group 2 learning mathematics without technology

μ_{PWG3} = Mean test results of the test participants from group 3 learning physics with technology.

μ_{PWOG3} = Mean test results of the test participants from group 3 learning physics without technology.

μ_{MWG3} = Mean test results of the test participants from group 3 learning mathematics with technology.

μ_{MWOG3} = Mean test results of the test participants from group 3 learning mathematics without technology.

Hypotheses for physics:

H_{0PG1}: There is no significant difference in the mean test scores of the students from group 1 learning physics with and without technology.

$$\therefore \mu_{PWG1} = \mu_{PWOG1}$$

H_{0PG2}: There is no significant difference in the mean test scores of the students from group 2 learning physics with and without technology.

$$\therefore \mu_{PWG2} = \mu_{PWOG2}$$

H_{0PG3}: There is no significant difference in the mean test scores of the students from group 3 learning physics with and without technology.

Hypotheses for mathematics:

H_{0MG1}: There is no significant difference in the mean test scores of the students from group 1 learning mathematics with and without technology.

$$\therefore \mu_{MWG3} = \mu_{MWOG3}$$

H_{0MG2}: There is no significant difference in the mean test scores of the students from group 2 learning mathematics with and without technology.

$$\therefore \mu_{MWG2} = \mu_{MWOG2}$$

H_{0MG3}: There is no significant difference in the mean test scores of the students from group 3 learning mathematics with and without technology.

$$\therefore \mu_{MWG3} = \mu_{MWOG3}$$

Table 7.3: Comparison of means of test scores of physics and mathematics for the participant from group 1 learning with and without technology

Engineering Concept	**Result**
Physics	P Value = 0.001 t_0^*= 3.32 Degrees of Freedom (Calculated) = 73 $t_{\alpha/2,DF}$ = 1.99

	Mean test score with technology = 71.34 > Mean test score without technology = 52.39 Since, $\lvert t_0^* \rvert > t_{\alpha/2,DF}$, We reject null hypothesis. There is a significant difference in the mean test scores of the students from group 1 learning physics with and without the help of mobile devices.
Mathematics	P Value = 0.148 t_0^*= 1.46 Degrees of Freedom (Calculated) = 74 $\mathrm{t}_{\alpha/2,\mathrm{DF}}$ = 1.99 Mean test score with technology = 68.92 > Mean test score without technology = 61.18 Since, $\lvert t_0^* \rvert < \mathrm{t}_{\alpha/2,\mathrm{DF}}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 learning mathematics with and without the help of mobile devices.

Significant differences in the mean test scores of the participants from group 1 using the mobile technology and not using the mobile technology for physics confirms the hypothesis that the mobile technology integration in the educational practices is effective for physics education for undergraduate students.

Table 7.4: Comparison of means of test scores of physics and mathematics for the participant from group 2 learning with and without technology

Engineering Concept	**Result**
Physics	P Value = 0.015 t_0^*= 2.48 Degrees of Freedom (Calculated) = 82 $t_{\alpha/2,DF}$ = 1.99 Mean test score with technology = 55.95 > Mean test score without technology = 42.93 Since, $\lvert t_0^* \rvert > t_{\alpha/2,DF}$, We reject null hypothesis. There is a <u>significant difference</u> in the mean test scores of the students from group 2 learning physics with and without the help of mobile devices.
Mathematics	P Value = 0.124 t_0^*= 1.55 Degrees of Freedom (Calculated) = 80 $\mathrm{t}_{\alpha/2,\mathrm{DF}}$ = 1.99 Mean test score with technology = 62.49 > Mean test score without technology = 54.84

	Since, $\lvert t_0^* \rvert < \mathrm{t}_{\alpha/2,\mathrm{DF}}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 2 learning mathematics with and without the help of mobile devices.

Significant differences in the mean test scores of the participants from group 2 using the mobile technology and not using the mobile technology for physics confirms the hypothesis that the mobile technology integration in the educational practices is effective for physics education for group of recent college graduates graduated for not more than 2 years.

Table 7.5: Comparison of means of test scores of physics and mathematics for the participant from group 3 learning with and without technology

Subject	**Result**
Physics	P Value = 0.002 t_0^*= 3.115 Degrees of Freedom (Calculated) = 74 $t_{\alpha/2,DF}$ = 1.99 Mean test score with technology = 66.03 > Mean test score without technology = 51.03 Since, $\lvert t_0^* \rvert > t_{\alpha/2,DF}$, We reject null hypothesis.

	There is a significant difference in the mean test scores of the students from group 3 learning physics with and without the help of mobile devices.
Mathematics	P Value = 0.002 t_0^*= 3.16 Degrees of Freedom (Calculated) = 74 $\mathrm{t}_{\alpha/2,\mathrm{DF}}$ = 1.99 Mean test score with technology = 67.66 > Mean test score without technology = 51.74 Since, $\|t_0^*\|$> $\mathrm{t}_{\alpha/2,\mathrm{DF}}$, We reject null hypothesis. There is no significant difference in the mean test scores of the students from group 2 learning mathematics with and without the help of mobile devices.

Significant differences in the mean test scores of the participants from group 3 using the mobile technology and not using the mobile technology confirms the hypothesis that the mobile technology integration in the educational practices is effective for group of college graduates graduated for more than 2 years.

7.3 BETWEEN GROUPS ANALYSIS – UNDERSTAND EFFECT OF TECHNOLOGY INTEGRATION AND ENGINEERING CONCEPTS ACROSS DIFFERENT STUDENT GROUPS

Table 7.6: Comparison of means of test scores between different subject groups for learning mathematics and physics with and without technology

Concept	Math		Physics		Math		Physics		Math		Physics	
Groups	Gp 1	Gp 2	Gp 1	Gp 2	Gp 2	Gp 3	Gp 2	Gp 3	Gp 1	Gp 3	Gp 1	Gp 3
With Technology	**μ**= 62.49	**μ** = 67.66	**μ** = 62.63	**μ** = 66.03	**μ**= 67.66	**μ**= 68.92	**μ**= 66.03	**μ**= 71.34	**μ**= 62.49	**μ**= 68.92	**μ**= 62.63	**μ**= 71.34
	P Value = 0.186		P Value = 0.49		P Value = 0.265		P Value = 0.49		P Value = 0.803		P Value = 0.303	
Without Technology	Mean = 54.83	Mean = 51.74	Mean = 42.93	Mean = 50.76	Mean = 51.74	Mean = 61.18	Mean = 50.76	Mean = 52.39	Mean = 54.83	Mean = 61.18	Mean = 42.93	Mean = 52.39
	P Value = 0.56		P Value = 0.111		P Value = 0.077		P Value = 0.76		P Value = 0.24		P Value = 0.085	

Table 7.7: Comparison of means of test scores between different subject groups for learning mathematics with technology

Groups under comparison	Statistics
Group 2 and Group 3	P Value = 0.265 t_0^*= -1.12 Degrees of Freedom (Calculated) = 77 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 2 and students from group 3 studying mathematics with technology.
Group 1 and Group 3	P Value = 0.803 t_0^*= 0.25 Degrees of Freedom (Calculated) = 74 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 and students from group 3 studying mathematics with technology.

Group 1 and Group 2	P Value = 0.186 t_0^*= 1.33 Degrees of Freedom (Calculated) = 74 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 and students from group 2 studying mathematics with technology.

Table 7.8: Comparison of means of test scores between different subject groups for learning physics with technology

Groups under comparison	Statistics
Group 1 & Group 3	P Value = 0.49 t_0^*= - 0.7 Degrees of Freedom (Calculated) = 79 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis.

	There is no significant difference between the mean test scores of the students from group 1 and students from group 3 studying physics with technology.
Group 2 & Group 3	P Value = 0.303 t_0^*= 1.036 Degrees of Freedom (Calculated) = 73 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 2 and students from group 3 studying physics with technology.
Group 1 & Group 2	P Value = 0.09 t_0^*= 1.68 Degrees of Freedom (Calculated) = 77 $t_{\alpha/2,DF}$ = 1.99 Since, $\lvert t_0^* \rvert < t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 and students from group 2 studying physics with technology.

Table 7.9: Comparison of means of test scores between different subject groups for learning mathematics without technology

Groups under comparison	Statistics
Group 2 & Group 3	P Value = 0.563 t_0^*= 0.581 Degrees of Freedom (Calculated) = 79 $t_{\alpha/2,DF}$ = 1.99 Since, $\|t_0^*\|$< $t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 2 and students from group 3 studying mathematics without technology.
Group 1 & Group 3	P Value = 0.077 t_0^*= 1.79 Degrees of Freedom (Calculated) = 74 $t_{\alpha/2,DF}$ = 1.99 Since, $\|t_0^*\|$< $t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 and students from group 3 studying mathematics without technology.

Group 1 & Group 2	P Value = 0.242 t_0^*= 1.177 Degrees of Freedom (Calculated) = 79 $t_{\alpha/2,DF}$ = 1.99 Since, $\|t_0^*\|$< $t_{\alpha/2,DF}$, We fail to reject null hypothesis. There is no significant difference between the mean test scores of the students from group 1 and students from group 2 studying mathematics without technology.

Table 7.10: Comparison of means of test scores between different subject groups for learning physics without technology

Groups under comparison	Statistics
Group 2 & Group 3	P Value = 0.111 t_0^*= - 1.61 Degrees of Freedom (Calculated) = 79 $t_{\alpha/2,DF}$ = 1.99 Since, $\|t_0^*\|$< $t_{\alpha/2,DF}$, We fail to reject null hypothesis.

	There is no <u>significant difference</u> between the mean test scores of the students from group 2 and students from group 3 studying physics without technology.
Group 1 & Group 3	P Value = 0.764 t_0^*= 0.3 Degrees of Freedom (Calculated) = 71 $\mathrm{t}_{\alpha/2,\mathrm{DF}}$ = 1.99 Since, $\lvert t_0^* \rvert < \mathrm{t}_{\alpha/2,\mathrm{DF}}$, We fail to reject null hypothesis. There is no <u>significant difference</u> between the mean test scores of the students from group 1 and students from group 3 studying physics without technology.
Group 1 & Group 2	P Value = 0.085 t_0^*= 1.742 Degrees of Freedom (Calculated) = 77 $\mathrm{t}_{\alpha/2,\mathrm{DF}}$ = 1.99 Since, $\lvert t_0^* \rvert < \mathrm{t}_{\alpha/2,\mathrm{DF}}$, We fail to reject null hypothesis. There is no <u>significant difference</u> between the mean test scores of the students from group 1 and students from group 2 studying physics without technology.

All between the subjects tests show that there are no significant differences in the mean test results between the test participants groups for mathematics and for physics for mobile technology application and for no mobile technology application. This suggests that the integration of mobile technology is helping improve the knowledge acquisition capability of individuals across the different groups.

7.4 3-WAY ANOVA

From the 3-way ANOVA analysis, the individual treatments of technology use, subject and participant levels show a significant impact on the test scores as outcome (P values 0.001, 0.033 and 0.001 respectively). Second level and third level interactions do not show any impact on the scores. Low P values for the individual factors show that each of the individual factors significantly impacts the output scores. A lack of evidence on second and third level interactions fails to prove that second and third level interactions show any significant difference in the mean test scores.

The distribution of standard deviation Vs. mean shows no pattern and it is randomly distributed. The same can be observed for distribution of variance Vs. mean. Therefore, it confirms the randomness and absence of any pattern.

Cross hair plot shows a distinct difference in means for both subjects for both technology application stimuli (with and without technology) for group 2 and group 3 students, but for undergraduate students the means show a crossover. This however suggests that for undergraduate students, learning math and physics with technology and learning these subjects without technology show equal means at some point. All the crosshair plots confirm that the means of test scores of all the students learning with technology show a higher mean compared to mean test results of the students learning without technology.

7.4.1 **Plots**

Spread-versus-Level Plots

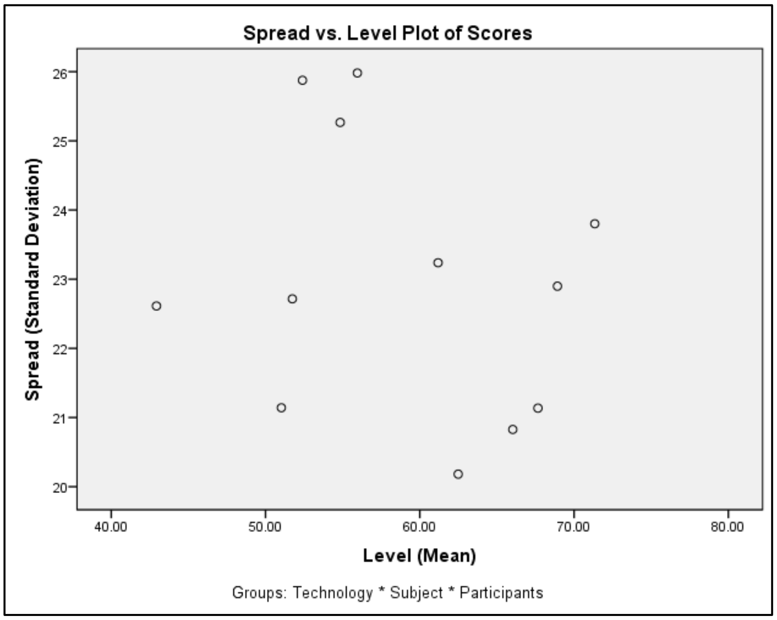

Figure 7.1: Plot of standard deviation Vs. means for three way interactions for all 3 factors

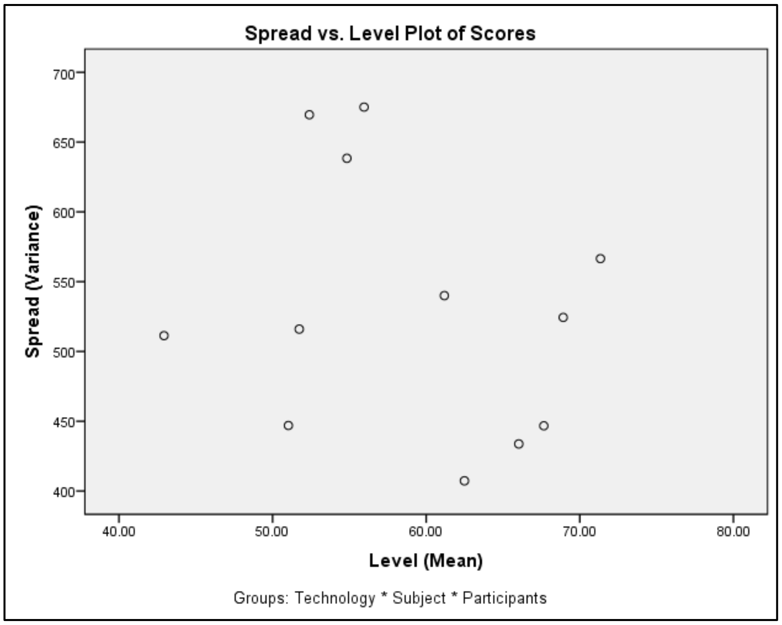

Figure 7.2: Plot of variance Vs. means for three way interactions for all 3 factors

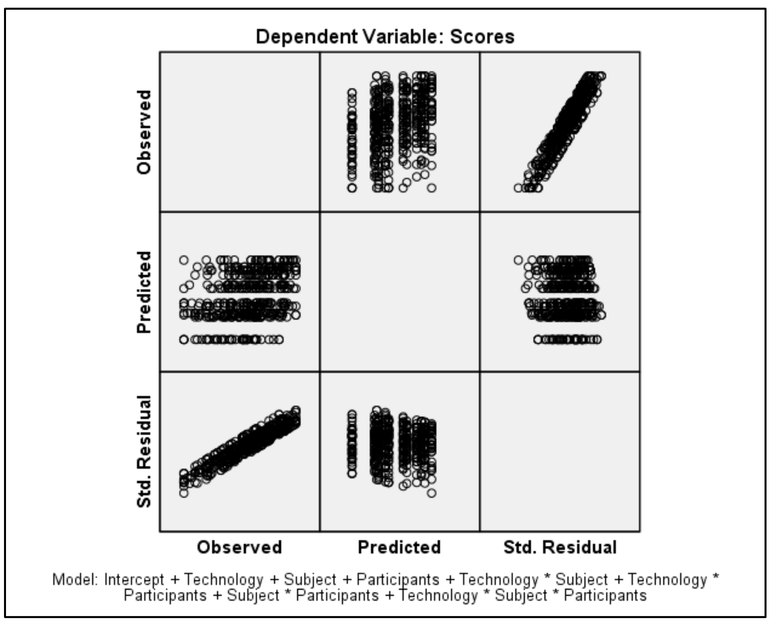

Figure 7.3: Plot of observed scores Vs residuals for three way interactions for all 3 factors

Profile Plots

Technology * Subject * Participants

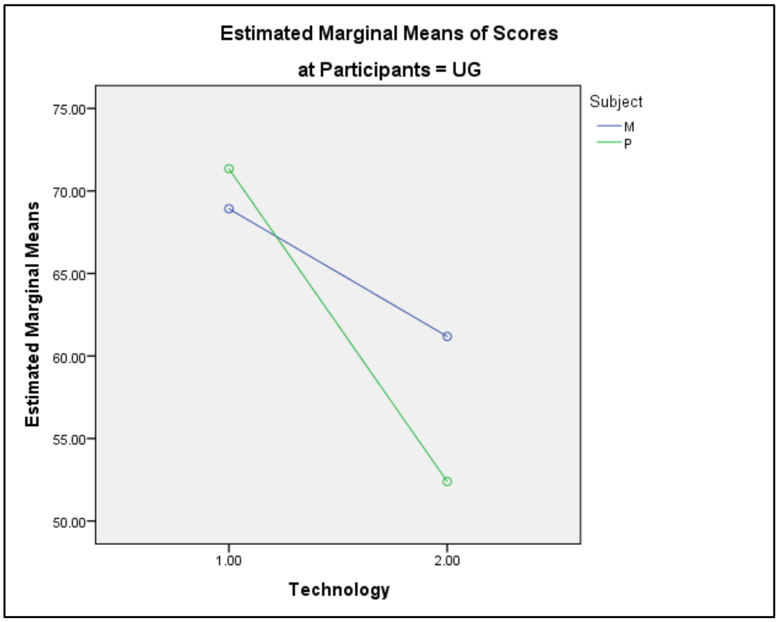

Figure 7.4: Plot of means for group 1 students for both technology application stimuli for mathematics and physics concepts

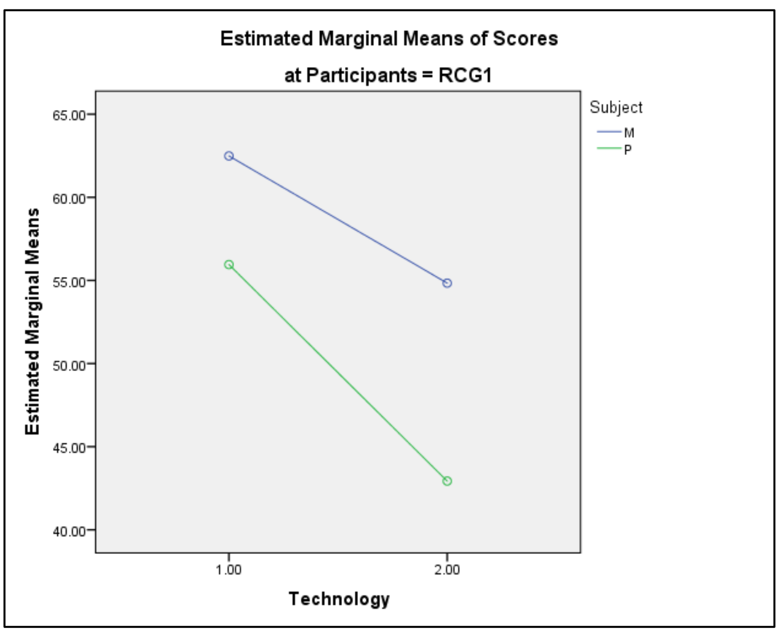

Figure 7.5: Plot of means for group 2 students for both technology application stimuli for mathematics and physics concepts

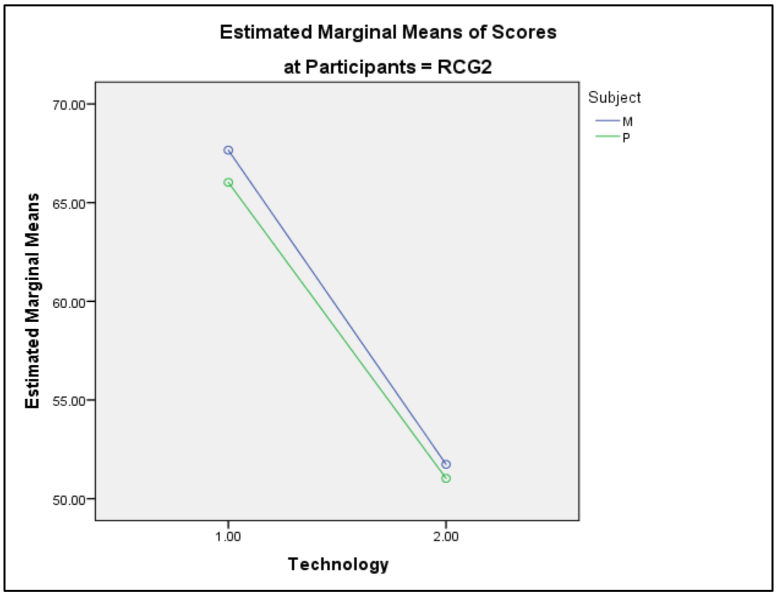

Figure 7.6: Plot of means for group 3 students for both technology application stimuli for mathematics and physics concepts

8 USER EXPERIENCE EVALUATION

This chapter details the results from the usability and user experience testing of the form factor and the tool. Findings from this study helped define the guidelines for the development of mobile-based augmented learning tool.

After the teaching session described in chapter 6, the test participants participated in 1:1 interviews. This interview session was designed to answer questions pertaining to the preferred form factor use. The interviews were also guided to understand the preferred augmentation components on the mobile-based augmented learning system. The questions were designed to probe the test participants on usefulness and intention to use mobile technology. These augmented learning assisting components included (Graphing Tool, videos, notes (writing on the tablet), notes (typing on the tablet), and additionally provided notes). The responses collected from the users were in the form of a 5-point likert scale measurement; 1 being not at all useful and 5 being extremely useful.

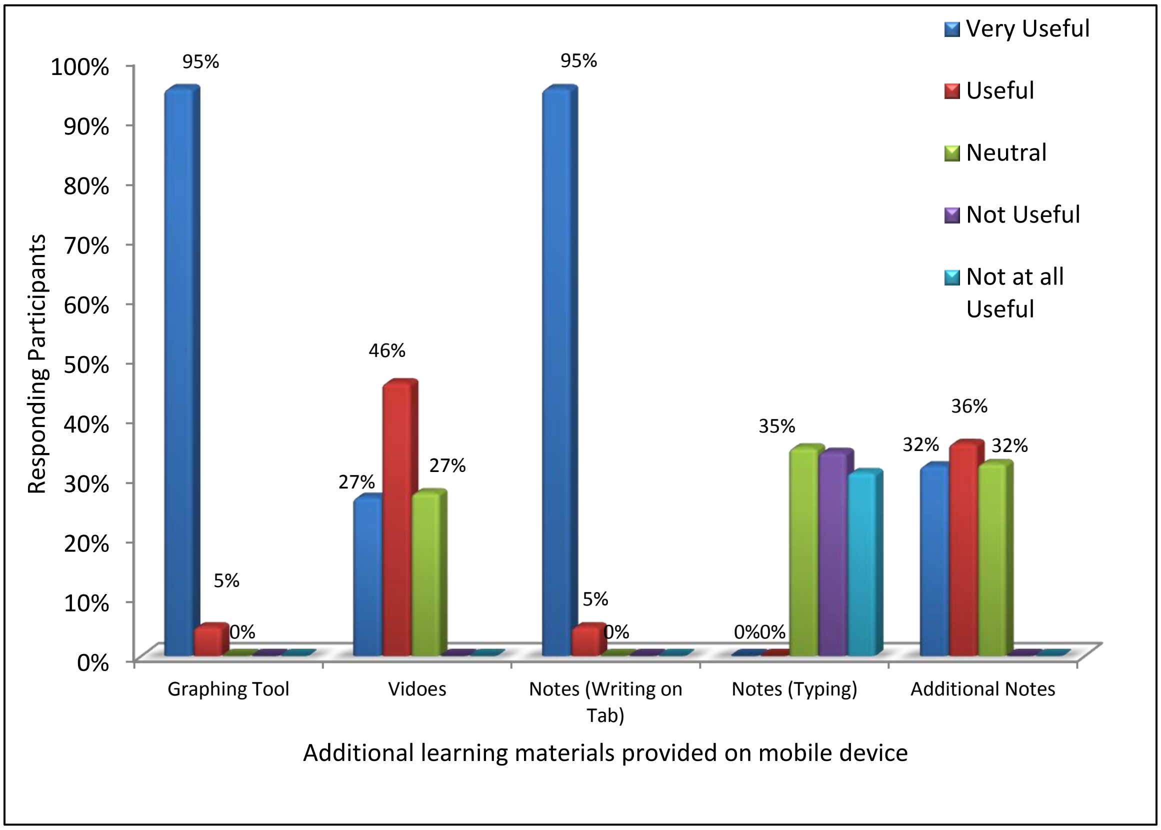

Figure 8.1: Responses about additional learning assistants collected from test participants

As shown in figure 8.1, it is clear that participants preferred to use the videos, graphing tools, and taking notes in the form of writing on the tab the most useful. The responses for the note taking in the form of typing on the tablet and seeing additional notes received mixed responses. Graphing tool and taking notes by writing on the tab were the most useful tools. There were no responses received from the test participants on these two tools which indicated that these two tools were not useful. For videos, positive responses were distributed between being very useful and being neutral. A similar trend was seen for additional notes. Typing experience for note taking was not really useful for the users and hence the responses were distributed equally between the tool being neutral and the tool being not at all useful.

In order to examine the device size preference, participants were asked questions on attributes such as mobility, portability as well as readability of the content on different screen sizes, pre-test and post-test. Following were the responses:

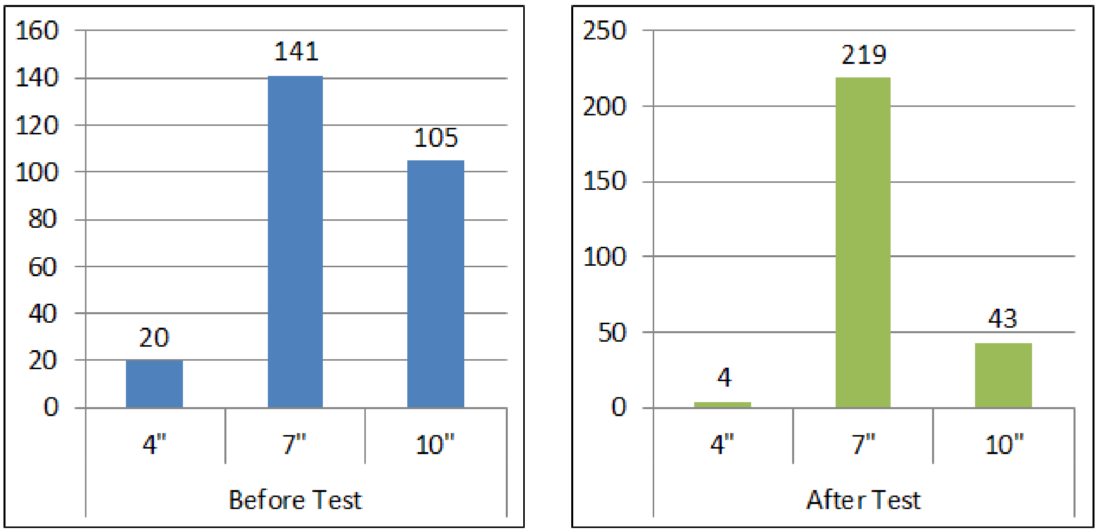

Figure 8.2: Responses collected from the test participants about their preferred mobile device size

Clearly, almost all the test participants believed that 7-inch tablet size was the most useful collectively as far as readability, portability and the mobility of the content was concerned.

Quotes from Student Participants

Positive Quotes

- *"This is an extremely useful tool"*
- *"I see myself using this tool in and outside the class"*
- *"I love the 7-inch device, it is portable, easy to read"*

- *“Math becomes really interesting here. I would love to learn differential equations”*
- *“I can use this in class? Amazing”*
- *“Using this tool is a no-brainer”*
- *“Extremely useful”*
- *“It is a convenient tool”*
- *“My chances of A grade in math using this are higher”*
- *“I wish this was available to us earlier. I struggled throughout my undergrad degree with complex math.”*
- *“If this tool is available to learn mechanics and probability, it would make everyone’s life easy”*
- *“Is this tool available only at WSU or everywhere?”*
- *“Clean UI with excellent haptic and visual feedback. Now I know what I am clicking on”*

Negative Quotes

- *“I would want more gaming type illustrations”*
- *“I don’t like mobile devices that much”*
- *“I don’t see myself using videos when I am in classroom”*

Figure 8.3: Testing Procedure.

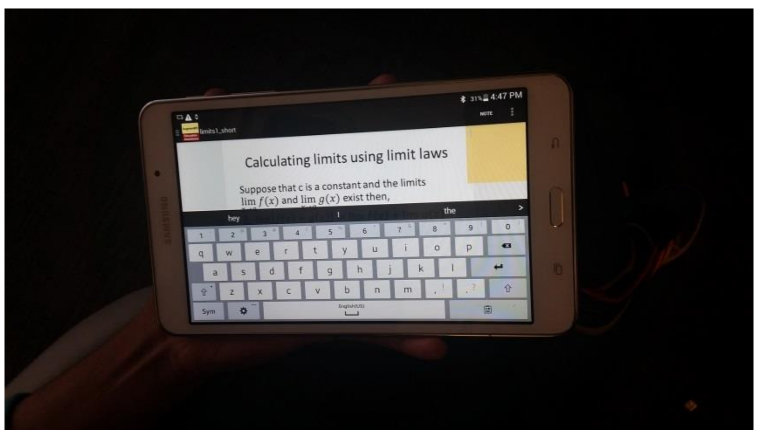

Figure 8.4: Mobile-Augmented Learning Assistant Showing Taking Notes by Typing Feature.

Figure 8.5: Mobile-Augmented Learning Assistant Showing Graphing Tool Feature.

Figure 8.6: Test Participants Learning with the help of Mobile- Augmented Learning Assistants.

9 MODEL DEVELOPMENT AND ANALYSIS OF THE MODEL

9.1 BACKGROUND

The effectiveness of integrating mobile devices in engineering education can be measured in multiple ways. Along with the measurement and comparison of formal test scores, measurement of user acceptance and behavior intention to utilize this form of technology is equally important. User acceptance of mobile technology and behavioral intention of users to accept and use this technology in educational settings needs to be identified and mapped. These responses are from questionnaires which are direct or indirect manifestations of the independent variable of behavioral intention. It becomes imperative to establish the validity of the responses collected from the student participants.

Quantified responses are the direct outcomes of questionnaire process that was administered to the student participants. In the context of this experiment, we have attempted to model the quantified responses collected from the students. This includes the mapping of students' behavioral intention along with several other attitudinal measurements. We can map and model user intention and behavior to make predictions about the overall success and effectiveness of the technology integration process. Behavioral intention can therefore serve as a measurement of success of the overall technology assisted education process.

The over model development process can be subdivided into several groupings of data. These data groups are nothing but attitudinal measurements which manifest underlying questionnaires. The data for these questionnaires is collected from users in the form of interviews and questionnaires [7][32][35][36][100][115][143][147][158]. Behavioral intention (BI) is defined as a person's perceived likelihood or "subjective probability that he or she will engage in a given behavior"[159]. The methods to establish the validity and the reliability of the measured data are discussed in the methods section. The combined factor of behavioral intention represents practical action from the user or test subject. Direct quotes which try to indicate something like “I intend to…” or “I would like to…” reflect behavior of the individual and quotes on the lines of “I plan to…” or “I will be…” indicate the intention. For behavioral measurement, the general question response category ranges from ‘highly unlikely’ to ‘highly likely’ and response category for intention generally varies from ‘definite true’ to ‘definite false’. Multiple theories have been proposed to try to understand the exact constitution of the human’s behavioral intention and the underlying attitudinal measures that constitute it. Among these theories are theory of reasoned action (TRA), Theory of planned behavior (TPB), unified theory of acceptance and use of technology (UTAUT) and Hybrid UTAUT model theories that have tried to emulate behavioral intention. TRA, designed by Azjen and Fishbein [7], suggests that intention heavily influences behavior. Intention, which is guided by a determined attitude turns into behavior. TPB, developed by Azjen, argues that multiple attitudinal and normative beliefs control a person’s behavior. Due to these beliefs and attitudes, behavior is severely influenced. TAM, which is a direct derivative of the TRA model, highlights the use of computers as a primary focus [7][36][143]. TAM focuses on defining perceived usefulness and perceived ease of use influenced by behavioral intention. TAM was developed by Moore and Benbasat [100], who have defined independent constructs such as compatibility, complexity, and trainability as attitudinal measurements and have also defined the measures to quantify them. There is one common link between these theories and that is the diffusion of the behavioral intention and the way it unifies the two complex attitudinal measurements, behavior and intention. This combination, behavioral intention indeed reflects a planned action to achieve a certain task or show extreme inclination/positivity towards achieving those things. For example, the statement, "I plan to (behavior) and I will (intention) run tonight for 30 minutes" tell us about determination and a very strong inclination towards achieving the goal of running for 30 minutes in the evening. Through existing theories (TAM, TPB, UTAUT and Hybrid UTAUT), attempts are made to understand the behavioral intention of the user towards different forms and instances of technology when presented with probing scenarios and tests [7][36][143][147].

There are multiple ways in which the prediction of the behavioral intention can be achieved. The first way is to collect the measurements through the questionnaire designed based on the manifestation of behavioral intention. This gives us a single indicator, multiple latent variables model. The second way is to understand the components that form the manifested variable of behavioral intention. As the name suggests, behavioral intention is formed by two attitudinal measurements, behavior and intention.

The objective of this division process is to understand the total effect of each sub module on the user's behavioral intention to use the technology. The division and individual testing process can also highlight the success of future implementation of such technology platforms. Our research is focused on determining, redesigning and understand the effect of the individual modules behavioral intention. This is achieved by conducting timely interviews and data collection through questionnaires from the participating students. The pillar/module research is steered towards understanding the strong modules in the model and therefore understand the anchor points on which maximum emphasis can be given to make the model robust. These modules are called constructs which are the measures of the individual elements that influence the behavioral intention of the user and the decision process towards the acceptance and future success of that technology integration.

There are several technology integration models which we can predict the behavioral intention of the users at a high level. We understand that there are still plenty of improvements needed in the current models. As the technology develops towards more ubiquitous nature and we see more of active users of this technology in the field of education, there are several other factors which should be tested independently as individual constructs. Also, the current state of the constructs can be improved significantly to better understand the effectiveness of the technology integration in the field of engineering education. Therefore, by redesigning the constructs, we can highlight the granular manifest variables that can momentously impact behavioral intention.

The redesigning of the constructs in more granular sub constructs can yield in better prediction of the behavioral intention of the technology users. In this research project, performed a detailed review of ten existing technology integration models in the field of information systems. Each of these ten models is comprised of several individual constructs. These components are responsible for considering several factors around the user to ultimately predict the users' behavior. This review section is an effort to compare and evaluate user acceptance of augmented information over small form factor devices in the field of engineering education. This review attempts to identify similarities, differences and ultimately, the effectiveness and shortcomings of each of these models. The models are listed below. This review process lead us to the development of sub modules or root constructs that have a significant impact on the users' behavioral intention. The significance of these sub modules was tested as a combined effect on the behavioral intention and as an individual effect on the same. The individual root constructs were tested over the responses collected from all student participants with the application of technology. These constructs represent the building factors for the users' behavioral intention towards the technology. The behavioral intention is a direct determinant of the user behavior [7]. If the output of the constructs is high, it conveys that there is a strong chance for the user to behave in an intended way.

The shortcomings of the individual models for the integration of technology of augmented information over small form factor devices in the field of engineering education are listed in the table below.

Table 9.1: Models and the individual core constructs under review

Individual Table	**Shortcomings (For the technology integration with the augmented information over small form factor devices)**
TRA: Theory of Reasoned Action	It is a generalized model. This model has to be redesigned to specific applications with several modifications. The direct implementation of this model of the changing technology and the changing attitudes and behaviors may not yield the intended results.

(Ajzen & Fishbein 1980)(Davis et al. 1989)(Vallerand et al. 1992)	
TAM: Technology Acceptance Model (Davis et al. 1989)	This is a generalized modification of TRA model. This model breaks the TRA model in granular root constructs to better predict the users' behavioral intention towards a general technology implementation. It is not really suited for small form factor device integration.
MM: Motivational Model	Designed for dynamic corporate applications. Again, it is a much generalized model and it is designed to predict the user behavior based on the surrounding situations. It is rarely applicable to the technology integration. The constructs however are extremely useful for the other models. This model serves as a sub-model for many other models.
TPB: Theory of Planned Behavior	This is an immediate derivative or the TRA model and it hardly considers the users' performance expectancy from the mobile devices.

C-TAM-TPB: Combined TAM and TPB	Though it is a combination of the TAM and TPB model, it does not consider the social factors and the performance expectancy of the mobile devices.
MPCU –Model of PC Utilization	This model is strictly designed for the use of PC as a technological assistance.
IDT – Innovation Diffusion Theory	This model forms the basis for the UTAUT model but still lacks to answer the impact of user experience and device usability.
SCT – Social Cognitive Theory	This model is limited in terms of considering the user experience impact on the student, the role and expectancies of and from the technology device.
UTAUT – Unified Theory of Acceptance and Use of Technology	This model is an extension of TAM which is adapted for smaller form factor devices. This model considers the age and gender biases as some of their prime constructs which in the current fast paced world are redundant.
Hybrid UTAUT – Hybrid	This is one of the most advanced models designed for the integration of mobile technology into education. though it is effective, several of

Unified Theory of Acceptance and Use of Technology	its root constructs can be combined which are designed around an individual's personal qualities and intrinsic motivation. This model has a very limited scope for the UX measurements which is a key deciding factor for the prediction of the user behavior.

In order to form a new model, we reviewed all the models and gathered the list of all the constructs that form these individual models.

Our next step was to design a new model by identifying shortcomings of the existing models. The primary interest here was to identify the impact of performance expectancy on the behavioral intention of the user. The performance and acceptability of the introduced technology is greatly influenced by the user experience of the technology. Users' overall decision about accepting a particular technology and in turn their behavioral intention are heavily impacted by user experience. Thus, it becomes imperative to analyze user experience as an independent construct. User experience (UX) as a construct is defined with 7 dimensions namely, 1) Usability, 2) Usefulness, 3) Desirability, 4) Credibility, 5) Accessibility, 6) Findable (technology or feature), and 7) Valuable (technology or feature) [102]. Therefore, the construct of UX will be decomposed as a collective measure of all of the aspects of user experience. For the other constructs of the model, we will be considering the combinations of some of the individual constructs. These constructs are designed through the literature review of some existing models. Through literature review, some basic constructs are also considered as part of model design which are critical in prediction of behavioral intention.

There are thirty three individual constructs in total in all of the models under study. Constructs, their root constructs and their definitions are as indicated in the following table [7][35][36][147][159]

Table 9.2: Overview of constructs

Number	**Name of the Construct**	**Sub-Constructs (Root Constructs) if any**	**Definition**	**Source of Design guidelines (From where the constructs are designed)**	**Models using the construct**
1	Attitude Toward behavior	Behavioral beliefs	An individual's positive or negative feelings about performing the target behavior.	Ajzen and Fishbein, 1980, Appendix B.	TRA, TPB, (C-TAM-TPB)
		Outcome Evaluation		Ajzen and Fishbein, 1980, Appendix A.	
2	Subjective Norm	Normative beliefs	The person's perception that most people who are important to him think he	Ajzen and Fishbein, 1980, Appendix B.	TRA, TAM, TPB, (C-TAM-TPB)
		Motivation to Comply		Ajzen and Fishbein, 1980, Appendix B.	

			should or should not perform the behavior in question.	Combined Subjective Norm defined by, Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	
3	Perceived Usefulness		The degree to which a person believes that using a particular system would enhance his or her job performance. (Davis, 1989)	Davis, 1989.	TAM, (C-TAM-TPB)
4	Perceived Ease of Use		The degree to which a person believes that using a particular system would be free of effort. (Davis, 1989)	Davis, 1989.	TAM

5	Extrinsic Motivation		The perception that users will want to perform an activity because it is perceived to be instrumental in achieving valued outcomes that are distinct from the activity itself, such as improved job performance, pay or promotions.	Davis, 1989. This construct is operationalized using all of the items of perceived usefulness from TAM model	MM
6	Intrinsic Motivation		The perception that the users will want to perform an activity for no apparent reinforcement other than the	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MM

			process of performing the activity per se.		
7	Perceived Behavioral Control		Reflects perceptions of internal and external constraints on behavior and encompasses self efficacy, resource facilitating conditions, and technology facilitating conditions.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	TPB, (C-TAM-TPB)
8	Job Fit		How the capabilities of a system enhance an individual's job performance.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU

9	Complexity		The degree to which a system or design is perceived as relatively difficult to use and understand.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU
10	Long term Consequences		These are outcomes that have a payoff in the future, such as increasing the flexibility to change jobs or increasing the opportunities for more meaningful work.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU
11	Affect Toward Use		Feelings of joy, elation, or pleasure; or depression, disgust, displeasure or despises associated with an	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU

			individual with a particular act.		
12	Social Factors		The individual's internalization of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU, UTAUT
13	Facilitating Conditions		Objective factors in the environment that observers agree make an act easy to do,	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	MPCU

			including the provision of computer support.		
14	Relative Advantage		The degree to which using an innovation is perceived as being better than using its precursor.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT
15	Ease of Use		The Degree to which using an innovation is perceived as being difficult to use.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT
16	Image		The degree to which use of an innovation is perceived to enhance one's image or status in one's social system.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT

17	Visibility		The degree to which the technology or the technology design is apparent to the sense of sight (Moore and Benbasat, 1991).	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT
18	Compatibility		The degree to which an innovation is perceived as being consistent with existing values, needs, and experiences of potential adopters.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT
19	Results Demonstrability		The degree to which the results of using the technology are observable and	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT

			communicable to others (Moore and Benbasat, 1991).		
20	Voluntariness of Use		How an individual perceives formal job requirements (Moore and Benbasat, 1991).	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	IDT
21	Performance Expectancy	Perceived Usefulness	Defined Earlier.	Wang, Y.S., Wu,M.C. & Wang H.Y. 2009.	SCT, UTAUT
		Extrinsic Motivation		Defined Earlier.	
		Job Fit		Defined Earlier.	
		Relative Advantage		Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	

		Outcome Expectations	Outcome expectations relate to the consequences of the behavior.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	
22	Personal expectancy		Momentary belief concerning the likelihood of following a particular technology being followed by a particular outcome (Shih, H.P. 2006).	Wang, Y.S., Wu,M.C. & Wang H.Y. 2009.	SCT
23	Self-Efficacy		Judgments of how well one can execute courses of action required to deal with prospective situations.	Wang, Y.S., Wu,M.C. & Wang H.Y. 2009.	SCT

24	Affect		An individual's linking of the behavior.	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	SCT
25	Anxiety				SCT
26	Effort Expectancy	Perceived Ease of Use	Defined Earlier.	Defined Earlier.	UTAUT
		Complexity			
		Ease of Use			
27	Social Influence	Subjective Norm	Defined Earlier.	Defined Earlier.	UTAUT
		Social Factors		Defined Earlier.	
		Image		Defined Earlier.	

28	Facilitating Conditions	Perceived Behavioral Control	Defined Earlier.	Defined Earlier.	UTAUT
		Facilitating Conditions		Defined Earlier.	
		Compatibility		Defined Earlier.	
29	Attitude Towards Technology	Attitude Toward Behavior	Defined Earlier.	Defined Earlier.	UTAUT
		Intrinsic Motivation		Defined Earlier.	
		Affect Toward Use		Defined Earlier.	
		Affect		Defined Earlier.	

30	Attainment Value		The personal importance of doing well with regard to self-schema and core personal values, such as achievement [in press].	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	Hybrid UTAUT
31	Mobility		It is the ease of carrying the technology device [in press].	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	Hybrid UTAUT
32	Self-Management of Learning		The extent of an individual perceives that he or she is self-disciplined and enables to engage in autonomous learning [in press].	Venkatesh, V., Morris, M., Davis, G., Davis, F., 2003.	Hybrid UTAUT

33	Perceived Enjoyment		Similar to the intrinsic motivation factor from TAM. It is an individual's performance or engagement in an activity due to his or her interest in the activity [in press].	Wang, Y.S., Wu,M.C. & Wang H.Y. 2009.	Hybrid UTAUT

From the color coding, we can see that some of the basic constructs are used as root constructs of the advanced constructs which are designed for more advanced applications of the technology. Based on the detailed review of the models, and the context of use in engineering education, we identified the relevant constructs and developed a new model as discussed in the next section.

9.2 NEW MODEL STRUCTURE – USER-CENTERED TECHNOLOGY ACCEPTANCE MODEL

The constructs of the user-centered technology acceptance model are as described in table 6. Table 6 explains the use of some of the existing constructs and the comprising root constructs. Table 6 also describes the new construct design Self-Perception and the User Experience (UX) construct which has 7 root constructs.

Table 9.3: User-centered Technology Acceptance Model and respective constructs

Name of the Construct	**Sub-Constructs (Root Constructs) if any**
Performance Expectancy	Perceived Usefulness
	Extrinsic Motivation
	Job Fit
	Relative Advantage
	Outcome Expectations
Effort Expectancy	Perceived Ease of Use

<table>
<tr><td rowspan="2"></td><td colspan="3">Complexity</td></tr>
<tr><td colspan="3">Ease of Use</td></tr>
<tr><td rowspan="3">Social Influence</td><td colspan="3">Subjective Norm</td></tr>
<tr><td colspan="3">Social Factors</td></tr>
<tr><td colspan="3">Image</td></tr>
<tr><td rowspan="3">Facilitating Conditions</td><td colspan="3">Perceived Behavioral Control</td></tr>
<tr><td colspan="3">Facilitating Conditions</td></tr>
<tr><td colspan="3">Compatibility</td></tr>
<tr><td rowspan="6">Self-Perception</td><td rowspan="5">Attitude Towards Technology</td><td rowspan="2">Attitude Towards Behavior</td><td>Behavioral Beliefs</td></tr>
<tr><td>Outcome Evaluations</td></tr>
<tr><td>Intrinsic Motivation</td><td rowspan="3"></td></tr>
<tr><td>Affect Towards Use</td></tr>
<tr><td>Affect</td></tr>
<tr><td>Self-Efficacy</td><td colspan="2"></td></tr>
</table>

	Attainment Value	
	Perceived Enjoyment	
	Self-Management of Learning	
Mobility		
UX	Usability	
	Desirability	
	Accessibility	
	Credibility	
	Findability	
	Usefulness	
	Valuability	

Figure 9.1: The User-centered Technology Acceptance Model Structure

Figure 9.1 shows the structure of the user-centered technology acceptance model. It shows the primary construct, called behavioral intention, seven secondary constructs, namely User Experience, Mobility, Facilitating Conditions, Effort Expectancy, Performance Expectancy, Social Influence and Self Perception. The figure also displays how each of the construct has been formed by showing the base constructs and their relationships with the secondary constructs.

9.3 TEST OF VALIDITY AND RELIABILITY

The reliability of the tests was measured by the Chronbach's Alpha test which is a proven test of the reliability and consistency of a set of scale or items such as Likert scale. Chronbach's alpha is the average value of the reliability coefficients for all possible combinations of items when split into two half sets. In Chronbach's alpha calculations, reliability is the proportion of the variance in the measurement scores that occurs due to differences in the true scores rather than due to random error.

The results table from the Chronbach Alpha test is in the appendix section.

The positive or negative relationship of the constructs with the behavioral intention is analyzed and calculated with the help of confirmatory factor analysis method (CFA) using structural equation modeling (SEM) path analysis method. The software used for the analysis is SPSS AMOS package. AMOS uses Bayesian analysis to improve estimates of model parameters. All the collected variables show high reliability. Chronbach's alpha for the overall set of variables is also very high (0.9). Therefore, the data can be considered reliable.

Structural Equation Modeling (SEM): SEM is a method employed to study the causal relationship between two or more variables. It allows understanding of the direct or indirect, positive or negative relationships. These relationships could be between two or more independent variables, either continuous or discrete, with one or more dependent variables, continuous or discrete. The basis of SEM is formed by the measured variables. Measured variables are also termed as indicators. These are also called as manifest variables. A latent variable or factor or construct is the unobserved variable which manifests the indicators. In other words, the latent variable is inferred from manifest variables [132]. The relationships between the manifest variables are defined by the measurement model. The structural model defines the relationship between the latent variables. One of the advantages to SEM, is that latent variables are free of random error. This is because error has been estimated and removed, leaving only a common variance.

Generally, to define the model diagrammatically, measured variables are indicated by rectangles or squares and latent variables are indicated by ellipses or circles. The goal in building a path diagram or other structural equation model is to find a model that fits the data well enough to serve as a useful representation of reality. In other words, the goal is to convey a meaningful representation of the collected data through SEM. The following table represents the descriptive statistics of the collected variables.

There are five steps involved in SEM construction:

1. Model Specification: The primary idea behind model definition and statistically assessing model validity and reliability is to define the relationship between the variables in the form of equations. The model consists of two types of variables namely, dependent and independent variables. The parameters to be estimated are:
    a. regression coefficients and
    b. Variances and covariances of the independent variables in the model.

The general representation of the regression model with the help of Bentler-Weeks algebraic representation is as follows:

$$\eta = \beta\eta + \gamma\xi$$

where if q is the number of dependent variables and r is the number of independent variables, η (eta) is a $q \times 1$ vector of dependent variables, β (beta) is a $q \times q$ matrix of regression coefficients between dependent variables, γ (gamma) is a $q \times r$ matrix of regression coefficients between dependent variables and independent variables, and ξ (xi) is a $r \times 1$ vector of independent variables. One of the major differences in regression and SEM is that in SEM even the dependent variables can be viewed as predictors.

2. Model Identification: For model identification, we need to count the number of data points and the number of parameters to be estimated. Variances and covariances in the sample covariance matrix from the data in SEM. If p is the number of measured variables, then the number of data points is $\frac{p(p+1)}{2}$. The number of parameters is found by adding together the number of regression coefficients, variances, and covariances that are to be estimated. In order for the model to be estimated, there need to be more data points than the parameters to be estimated. Hypothesized model with more data points than the number of parameters to be estimated is called over identified model. Hypothesized model with equal number of data points and parameters to be estimated is called just estimated model and the hypothesized model with less number of data points compared to the number of parameters to be estimated is called as an under identified model.
3. Model Estimation: The goal of estimation is to minimize the difference between the structured and unstructured estimated population covariance matrices.
4. Testing Model Fit : The goal of estimation is to minimize the difference between the structured and unstructured estimated population covariance matrices. To accomplish this goal a function, F, is minimized where, $F = \left(s - \sigma(\phi)\right)W(s - \sigma(\phi))$, **s** is the vector of data (the observed sample covariance matrix stacked into a vector); s is the vector of the estimated population covariance matrix (again,

stacked into a vector) and (Q) indicates that s is derived from the parameters (the regression coefficients, variances and covariances) of the model. **W** is the matrix that weights the squared differences between the sample and estimated population covariance matrix. In EFA, the observed and reproduced correlation matrices are compared. This idea is extended in SEM to include a statistical test of the differences between the estimated structured and unstructured population covariance matrices. If the weight matrix, **W**, is chosen correctly, at the minimum with the optimal, F multiplied by $(N - 1)$ yields a chi-square test statistic. There are many different estimation techniques in SEM, these techniques vary by the choice of **W**.

5. Model Manipulation: Model manipulation is the mathematical adjustment process to eliminate the low weighted indicators. This is a valid process to eliminate the unwanted data elements which do not cause any difference to the model by their absence [18][19][141][142].

9.4 CONSTRUCTS AND ANALYSIS PER CONSTRUCT

9.4.1 Behavioral Intention (BI)

Behavioral Intention is defined earlier.

Model Output:

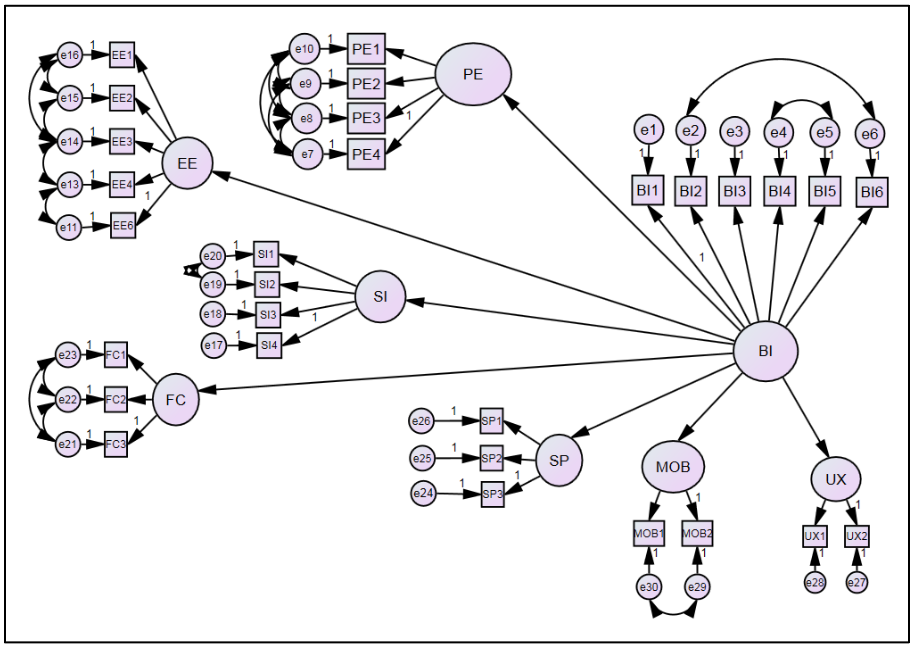

Figure 9.2: Behavioral Intention (BI) Model with the underlying constructs of Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Self-Perception (SP), Mobility (MOB) and User Experience (UX)

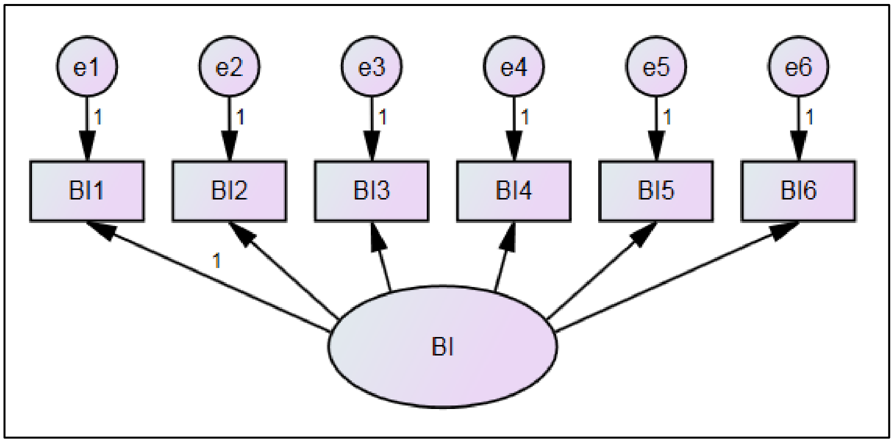

Figure 9.3: Behavioral Intention (BI) as a standalone model. This structure of the model is achieved by collecting the responses to the questions designed specifically for this construct.

9.4.2 Performance Expectancy (PE)

It is defined as the expectation an individual possesses about his or her performance while performing a job with the help of technology or aid. There are five underlying constructs that help the formation of performance expectancy. These base constructs are:

1. Perceived Usefulness (PU): It is the impression that an individual form about the technology or the aid he or she is using through actual use of it.
2. Extrinsic Motivation (EM): It is the motivation received by an individual from the surrounding factors such as peers or relatives or friends and family members.
3. Job Fit (JF): It is the individual's perception about the technology about just how good of an aid it is to perform the job.
4. Relative Advantage (RA): It is the feeling of advantage the individual feels by using the technology to perform the job.

5. Outcome Expectations (OE): These are the expected outcomes by the individual from the job. The performance on the job could be technology assisted or without any technology assistance [35][36][147].

Model outcome:

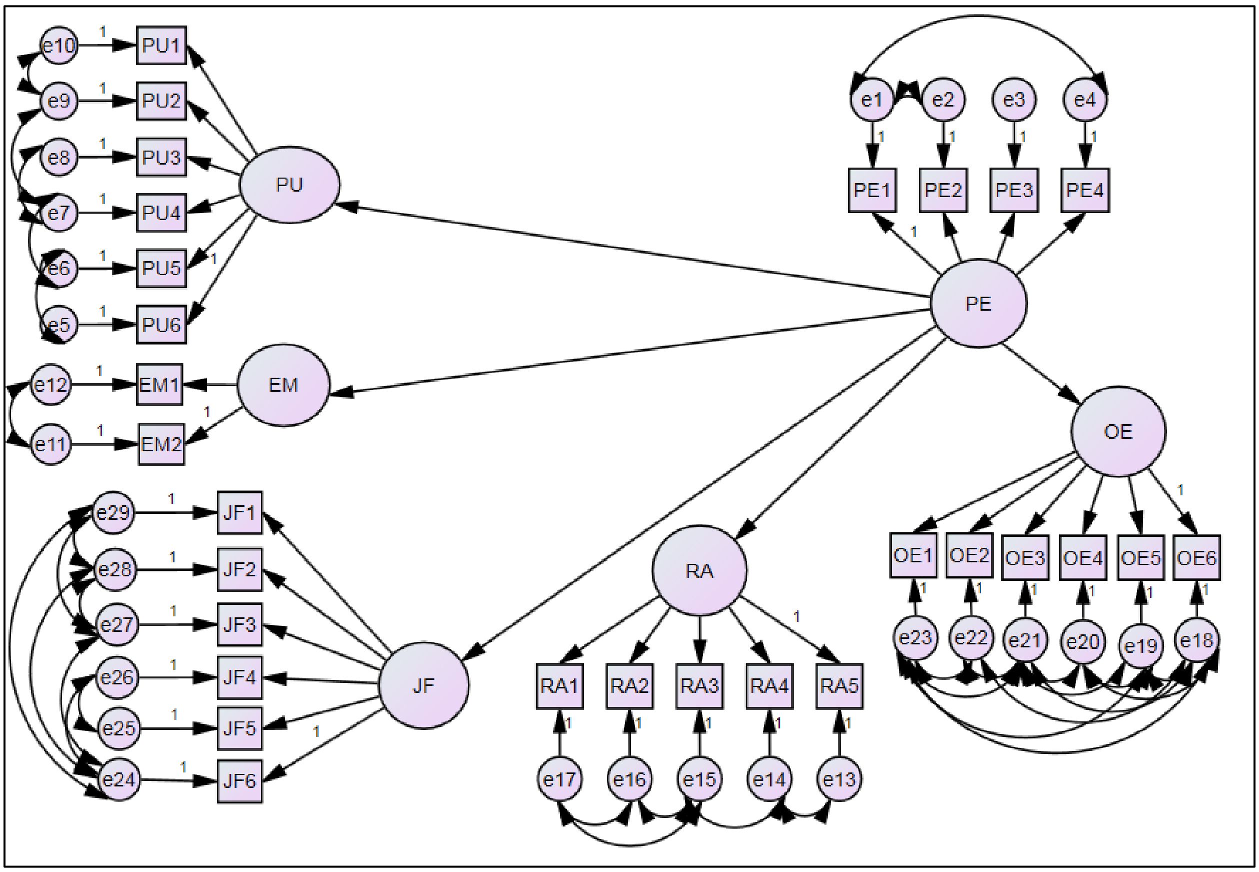

Figure 9.4: Performance Expectancy (PE) Model with the underlying constructs of Perceived Usefulness (PU), Extrinsic Motivation (EM), Job Fit (JF), Relative Advantage (RA), and Outcome Expectance (OE)

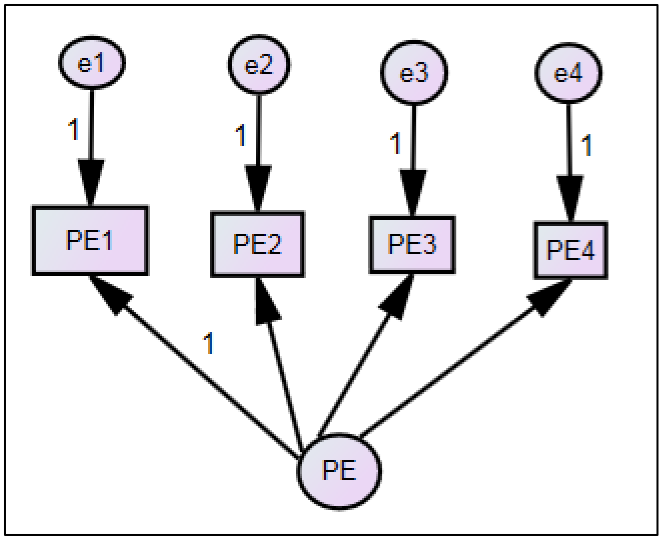

Figure 9.5: Performance Expectancy as a standalone construct. This structure of the model is achieved by collecting the responses to the questions designed specifically for this construct.

9.4.3 Effort Expectance (EE)

Effort Expectancy is defined as the expectation of investment of efforts pertaining to certain technology a user has while doing a job with the help of the technology. Effort expectancy is formed by three underlying constructs namely:

1. Perceived ease of use: It is the impression by the user about the use of technology about the overall usability and how easy to use that system is.
2. Complexity: It is exactly the opposite perception of the usability. It is a perceived image of the technology under use from the complexity perspective, that is how complex a system is of use overall.
3. Ease of use: Ease of use defines the overall usability and ease of use index for the system. It is formed by the average of responses collected for the usability index of the system from multiple users. Since it is an average of the

several perceptions of ease of use, it can very well be called as the actual indexed ease of use for the system.

For the simulated experimental conditions, to minimize the cognitive load on the test participants, Effort Expectancy construct was measured as a collective response (as a standalone construct) [35][36][147]..

Model Outcome:

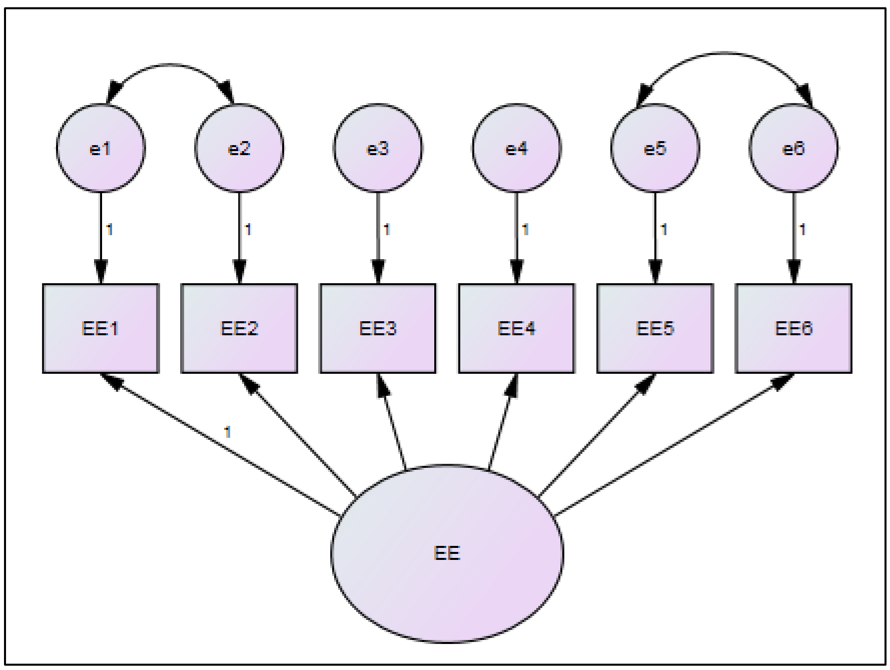

Figure 9.6: Effort Expectancy (EE) as a Standalone Construct. This structure of the model is achieved by collecting the responses to the questions designed specifically for this construct.

9.4.4 Social Influence (SI)

The degree to which an individual perceives that others are important to him/her in using new system. Constructs of subjective norm (SN), social factors (SF), and image (IM) are influential in the development of the social influence construct.

1. Subjective Norm (SN): A subjective measure of the social influence or pressure that results in engagement of the individual into a behavior. Subjective norms construct is formed by two underlying construct which are:

    a. Normative Beliefs: A typical set of beliefs passed from generations and families which typically define the individual’s actions in certain situations.

    b. Motivation to comply: The amount of encouragement an individual receives to obey the rules or the nature of the job to be performed.

    Because of the nature of the experimental setup, we have collected the subjective norm (SN) construct as a collective standalone construct.

2. Social Factors (SF): The factors around and individual in social settings that heavily influence the decision as well as the behavior.

3. Image (IM): A perceived image of the job a user has formed in his or her mind [35][36][147].

Model Output:

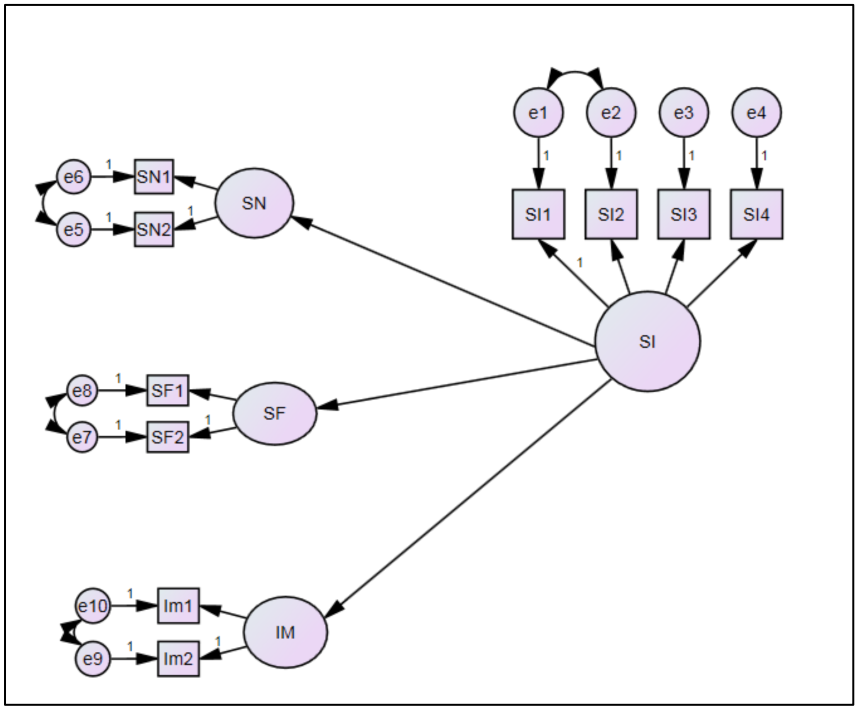

Figure 9.7: Social Influence (SI) Model with the underlying constructs of Subjective Norm (SN), Social Factors (SF), and Image (IM)

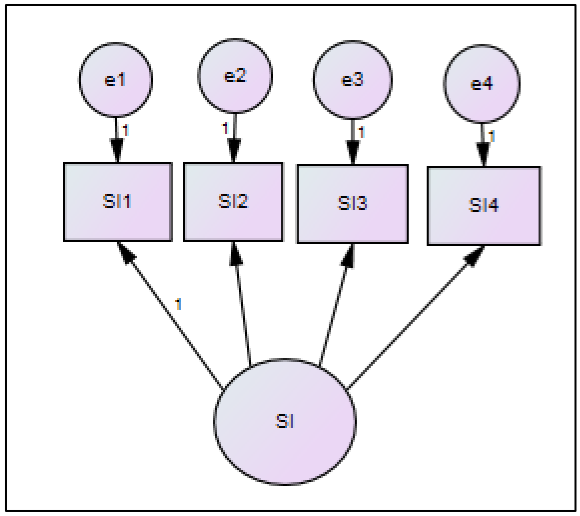

Figure 9.8: Social Influence as a Standalone Construct. This structure of the model is achieved by collecting the responses to the questions designed specifically for this construct.

9.4.5 Facilitating Conditions (FC)

Facilitating conditions are the primary surrounding conditions that define the job to be performed. Facilitating conditions form the overall surroundings of the job, also it defines the necessary behavior required to perform the job. This construct is formed by two underlying constructs namely:

1. Perceived Behavioral Control (PBC): The perception of an individual about the necessary behavior and the control of behavior that individuals need while performing a job.
2. Compatibility (C): It is the compliance needed to be showcased by the individual in order to perform the job with the help of technology.

Model Output:

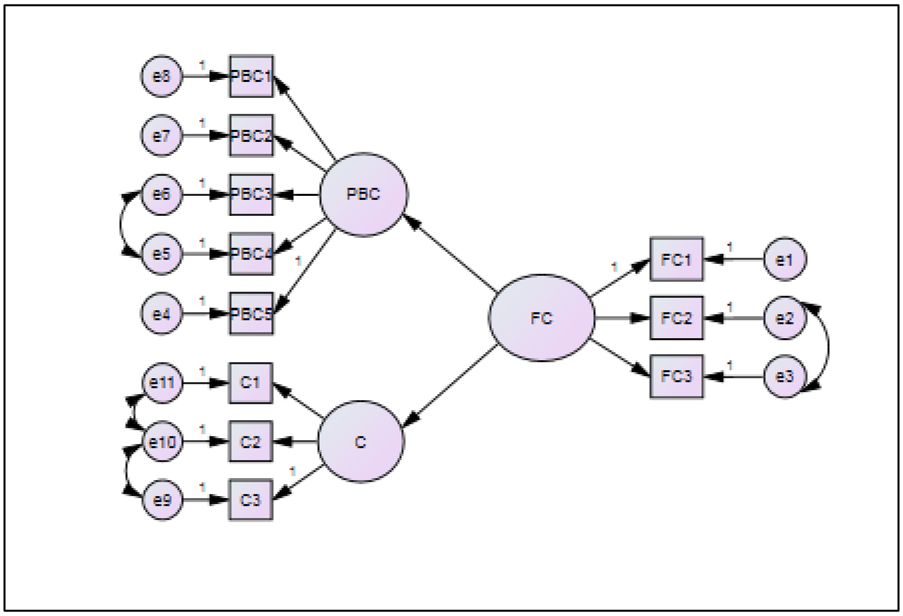

Figure 9.9: Facilitating Conditions (FC) Model with the underlying constructs of Perceived Behavioral Control (PBC), and Compatibility (C)

9.4.6 Self-Perception (SP)

Self-Perception (SP) is defined as the level of cognition an individual achieves while performing a certain task. In this case specifically, it is the perception of knowledge for the individual. Self-perception manifests five constructs: Attitude toward technology, self-efficacy, attainment value, perceived enjoyment, and self-management of learning. The construct attainment value was not a valid measurement and thus needed to be ignored.

1. Attitude toward technology (ATT): Attitude toward technology is the positive or negative feeling about the presented technology. Attitude toward technology manifests four constructs namely:

a. Attitude toward behavior (ATB): An individual's positive or negative feeling toward their overall behavior toward technology. This construct manifests two sub-constructs, namely:

i. Behavioral beliefs (BB): These are the beliefs with which an individual is raised or groomed.

ii. Outcome Evaluations (OE): Outcome evaluations are the projected outcomes from the process. In this case, these are the expected outcomes from the technology-based learning.

b. Intrinsic motivation (IM): The measurement of the internal drive to achieve the given job.

c. Affect toward Use (ATU): The direct effect on an individual's behavior by using certain technology.

d. Affect (A): The perceived direct outcome of using technology as aid.

2. Self-efficacy (SA): An individual's belief in his or her ability to succeed.

3. Perceived Enjoyment (PE): It is an individual's perception about the joyfulness or enjoyment he or she would receive by using the technology.

4. Self-management of learning (SML): It is the overall process of how an individual manages the process of learning.

Model Output:

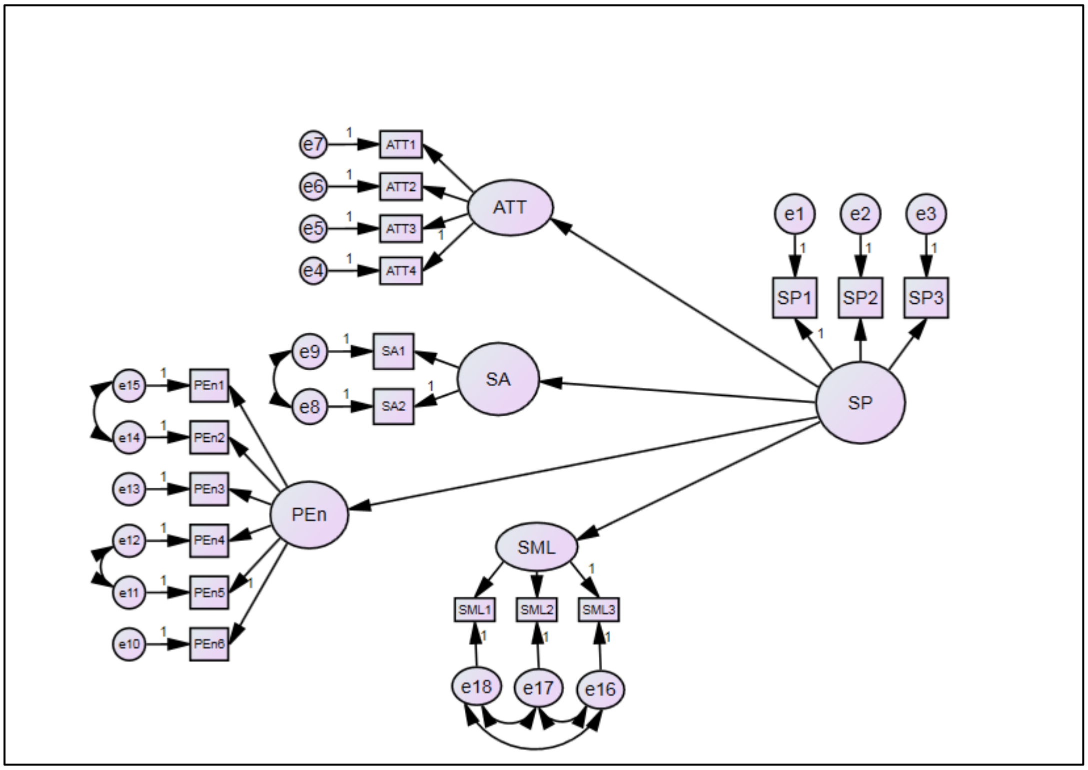

Figure 9.10: Self-Perception (SP) Model with the underlying constructs of Attitude toward technology (ATT), Self-efficacy (SA), Perceived enjoyment (Pen), and Self-management of learning (SML)

9.4.7 User Experience (UX)

User experience is overall image of the system in the users' mind about the overall usability and ease of use of the system. It manifests seven base constructs, namely: usability, desirability, accessibility, credibility, findability, usefulness, and valuability. Credibility, findability, usefulness and valuability was not applicable in this context of testing. Therefore, only usability, desirability, and accessibility are considered for analysis.

1. Usability (USA): Usability is the ease of use and learnability of a human-made object such as technology.
2. Desirability (DES): It is the degree to which an individual's desire to use the technology.
3. Accessibility (ACC): Accessibility defines the ease of access of the content while using the technology.

Model Output:

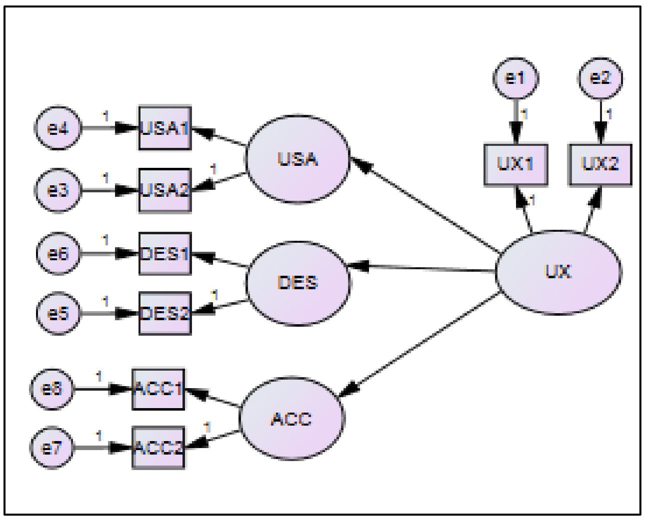

Figure 9.11: User Experience (UX) Model with the underlying constructs of Usability (USA), Desirability (DES), and Accessibility (ACC)

9.5 MODEL RESULTS DISCUSSION

Following table explains the values of fit indices from the analysis and the conclusions about each construct. Fit indices are Gross Fit Index (GFI) and Adjusted GFI (AGFI). Combination of values GFI and AGFI are considered strongly for determining validity of the analyzed models. Models with GFI and AGFI values close to 0.9 and up are considered to be valid and reliable [141][142].

Table 9.4: Fit indices values and conclusions of all constructs.

Constructs	P Value	GFI	AGFI	RMSEA	Conclusion
Behavioral Intention-Full	0.001	0.86	0.83	0.37	Model is marginally acceptable
Behavioral Intention-Standalone	0.515	0.986	0.967	0.0001	Model is acceptable
Performance Expectancy - Full	0.0001	0.797	0.744	0.069	Model is not acceptable
Performance Expectancy - Standalone	0.511	0.996	0.982	0.0001	Model is acceptable
Effort Expectancy - Standalone	0.318	0.986	0.958	0.03	Model is acceptable
Social Influence – Full	0.0001	0.912	0.843	0.097	Model is acceptable
Social Influence – Standalone	0.356	0.994	0.972	0.013	Model is acceptable
Facilitating Conditions - Full	0.002	0.927	0.880	0.063	Model is acceptable
Self-Perception - Full	0.155	0.925	0.9	0.026	Model is acceptable
User Experience – Full	0.534	0.975	0.954	0.0001	Model is acceptable

10 DISCUSSIONS

This chapter presents the results discussion of this project along the different phases of the study.

10.1 PHASE 1: CONCEPT IDENTIFICATION

The initiation of this dissertation was conducted with a series of detailed user-centered interviews and data collection through questionnaires. The data collected in this phase strongly highlighted the need for augmented learning tool to supplement the traditional classroom learning. A detailed literature review on learning and teaching trends also highlighted the usefulness of technology assistance. The literature review of the learning taxonomy led us to understand the necessity for the technology assistant and informal learning practices to be introduced to the students.

10.2 RESULTS DISCUSSION - STATISTICAL EXPERIMENTAL DESIGN AND MODEL DEVELOPMENT

Mobile-based learning experiment began by understanding the affordances of the learning aid offered to the students. These learning aids included items such as notes, additional videos, graphing tool, and so on. As a part of experimental design, students were taught basic topics in mathematics and physics (Limits and Derivatives, Newton's Laws of Motion and Friction) with and without using mobile learning assistant.

To prove the success of the mobile augmented learning assistant, our hypothesis stated that we should see a significant difference in the performance of formal tests between all of the students studying with and without technology. Statistical tests to compare the means of test scores for every engineering concept for students learning with and without technology show a significant difference. The use of technology allowed students to perform better than without technology across the engineering concepts.

Second hypothesis was to test the effectiveness of technology integration for individual student groups. For all student groups, there is a significant difference in the mean test results for physics concept for the students learning with and without technology. For the students who have graduated from the undergraduate degree program for more than two years, introduction of technology in learning mathematics shows significant improvement in the mean test results compared to no technology supported learning. Hypothesis testing was conducted with the assumption that all of the student participants from the same group were at an equal knowledge retention level. This assumption was employed due to the fact that there is no proven method to test the actual knowledge retention. Through balancing the test groups, we have tried to eliminate this problem of imbalance in the retention levels of the test participants.

Our third hypothesis was for the comparison of test scores between different student groups. This hypothesis testing ensured that the performance enhancement for the students learning with the help of technology was consistent for all groups. Therefore, we should not have seen any significant difference in the performance of individual student group for any particular learning concept with the stimulus of learning either with or without technology. The means comparison test reveals that there is no significant difference between any subject groups for any of the engineering concepts under test learning either with or without technology. This hypothesis testing proves that the application of technology impacts all of the student groups, either current or who have graduated from the engineering degree program equally allowing them to acquire the knowledge with equal potential.

From the model development process, and from the questionnaire-based data collection, we could confer that user experience is one of the key determinants for the behavioral intention. From the data analysis, we also can deduce that the model definition is valid and the data that was collected to support the designed model is reliable. The data validity is also established with the help of Chronbach Alpha analysis on every questionnaire response. Confirmation of the reliability with the help of structural equation modeling technique with confirmatory factor analysis proves the validity of the entire model as well as its reliability.

10.3 RESULTS OF STRUCTURAL EQUATION MODELING

From the SEM analysis of the UCTAM model, it is evident that the behavioral intention towards acceptance of mobile technology as a learning assistant, user experience are important constructs of the model that increase the adoption of technology integration. User experience acts as a significant dimension of analysis towards the overall attitude of user. Stable values of fit indices of every individual attitudinal measurement ensures that the collected data was valid and reliable. Along with ensuring the validity of behavioral intention, individual model analyses also result in the stability of root constructs or attitudinal measurements. This in turn confirms our belief that the primary decision variable of behavioral intention manifests each attitudinal variable. Through SEM we were able to establish the path connections of the individual attitudinal measurements to the behavioral intention. Proposed model structure of the model stands valid through the validity and reliability measurements of the collected data from the student participants.

10.4 USER EXPERIENCE EVALUATION

Another set of data collected from the students in the form of open ended 1:1 qualitative interviews confirms that the use of 7-inch tablet devices are ideally suited and sized for classroom learning. The device size adds to the portability, and excellent content presentation with clarity. Students mostly favored the notes, graphing tool, videos as the main aids supportive to the classroom learning. This confirms multiple hypotheses presented in this thesis document, confirming the overall success of the technology integration effort. Additional learning assistants present on the mobile-based augmented learning system can only function through the affordances offered by this device. Keeping the in-context awareness and environmental orientation intact, mobile-devices prove to be an excellent platform for hosting educational support systems. Through these affordances, mobile devices not only allow students to be engaged but also allow for an emotional connection between learning content and the learner. Through the ability to present multimedia data, mobile platforms allow the learners to learn through multiple sensory channels, maintaining their orientation with the surrounding world.

10.4.1 Mobile-Based Augmented Learning System Design Guidelines

Primary lecture content which is available to the entire class in testing procedure in the form of PowerPoint® slides. These slides are on the mobile devices in the form of stack of slides. The access to the entire primary lecture content is through sliding the images from right-to-left for next slide and left-to-right for the previous one (similar to image roll on mobile devices). Each lecture is in the form of an individual app. Along with the primary learning content, assistance was provided to the students in the form of augmented additional learning content. The overall design guidelines for the inclusion of these additional learning cues are explained in the following table. These guidelines will act as ground rules to design any mobile-based augmented educational assistant systems in the future.

Table 10.1: Design Guidelines for the Mobile-Based Augmented Learning Assistant

Feature	Guidelines
Understand your Users	
Detailed User Analysis	To provide mobile technology support to the students, it is mandatory to understand their working environment and practices, their difficulties as well as possible solutions that they are thinking of.
Keep it Simple	
Ease of Use	System design should be user friendly. Design should be assessed on the user experience honeycomb guidelines.
Aesthetic Integrity	1. The interface may not be extremely beautiful with flashing colors but the arrangement of the content needs to be extremely logical. The arrangement and presentation of the primary content needs to be consistent. 2. All the additional action buttons need to be of equal size and styled for consistency. This ensures the technology credibility for users.
Planned Content	Presented content needs to be planned with the subject matter experts and instructors. Content should not be random and outside syllabus.
Ease of Navigation	Content provided by the technology should support the easy navigation throughout. Paths to the content and the current content page/slide/tab needs to be shown clearly.

Keep Students in Context	
Offer in Context Access	With the technology introduction, it is important that the student is able to access the additional learning assistants along with the primary learning content.
Primary Content	1. Need to provide students with note making with typing on the screen as well as an option of free hand drawing notes to save these notes with the primary content. 2. Need to provide ability for the students to access any part of the overall content. This ensures a freedom to browse through the content to make themselves familiarized with the content better.
Seamless Integration	Introduced technology should be able to go along with the traditional learning practices as well. Teaching and learning styles should not have to change drastically due to technology application.
Blended approach	Secondary learning content should be designed in a blended fashion so that it does not appear foreign. This means that not only color schemes but the appearance and presentation of the secondary content should complement the primary learning content.
Non-disruptive	Introduced technology needs to be non-disruptive. Its use should be natural and complementing the classroom. Students should not lose their orientation and eventually classroom interest while using the technology. Their mental presence in the classroom should not be disturbed.

One of the most important features of this mobile-based augmented learning content is that only the keywords of interest are highlighted and provided additional information over. The additional information cues are selected with careful inspection so that they provide the optimum learning support to the students. The design of the mobile-based augmented learning follows the detailed guidelines designed in the Interactions and modeling lab preserve the learning and interacting surroundings of the students. The students do not lose their original learning and interacting context and orientation.

11 RESEARCH IMPLICATIONS

This study investigated the effectiveness of mobile-based learning system that can augment classroom learning. Leveraging the affordances, we designed a mobile augmented education tool for basic math and physics concepts that allows access to information and additional learning content within the context of classroom learning. Results from the study indicate that there is significant improvement in overall performance in mathematics and physics for the students who learnt these concepts with the help of mobile augmented educational assistant. With education moving from formal education practices to informal and collaborative education practices, mobile devices are playing a major role in the transition process. This research is an attempt to provide students with an ability to leverage their day-to-day devices to assist them with the learning content for better knowledge acquisition.

From the background research and the pilot research conducted, we identified several gaps between the learner, learning content, and instructor. These gaps are in the form of formal education practices, non-clarity of the content, lack of additional help, low understanding of function behaviors, no connection with real world problems while learning in the classroom settings and so on. In order to address these gaps, we developed a mobile-based augmented learning content that allows students to tap into additional learning content seamlessly right within the classroom settings. Through our testing procedure, we found that without losing the contextual awareness of classrooms, students access this additional information. Through the statistical analyses, we proved that the developed mobile augmented learning content is useful for the students to learn physics and mathematics.

This research contributes to the body of knowledge in mobile-based augmented learning system and model verification. The results of this research have both theoretical and practical implications. The theoretical contributions are based on the direct outcomes of the user experience research data gathering from the student participants. The data collected from the student participants led to the development of design guidelines for the mobile augmented learning system. Questionnaire-based data collected from the students led to the development of user-centered technology acceptance model which attempts to predict the behavioral intention of the students with the help of measurement of few basic attitudinal attributes. The practical implications include a mobile-augmented learning system that is implemented with the classroom learning content. Through a systematic development of this learning assisting system along with the user-centered testing technique, we have developed a framework for understanding the challenges for the students in learning process and provide a non-disruptive, inexpensive and seamless solution to assist them with knowledge acquisition. The development of the mobile augmented learning system has already been a basis for the temporal brain pattern understanding project with the help of mobile augmented learning system based math learning [67].

This research also presents a robust attitudinal measurement model that allows for measuring the acceptance of technology use among the students along with mapping of their attitudes towards it. The development of User Centered Technology Acceptance Model can help the researchers predict the behavioral intention of the students by understanding a few underlying attitudinal attributes. It also holistically establishes the validity as well as reliability in the collected data to confirm the validity and reliability of the model. The model is scalable with multiple different applications as formation of trends to understand possible success of many technologies to be introduced.

This research can be potentially extended to other areas of training such as applications in the field of medical training and therapeutic rehabilitations. In the current world, the recovery and training procedures are becoming more mobile-based. An in-context mobile-based learning application can prove to be an inexpensive yet effective. The effectiveness of the application can be tested with the actual application results as well as with the attitudinal analysis with the help of SEM. A detailed analysis of behavioral intention of the patients can lead to the conclusion of comprehensive analysis of success of such training assistants.

However, there are a few limitations to this study such as assumption of the retention level of the students belonging to just one group. This assumption was considered in the current study because there is no formal method to test for the retention. This can be resolved in the future by understanding the detailed learning history then testing the students with the retention test. Since this was not a longitudinal study, one more limitation was that we were not able to understand the long-term learning effects with the help of mobile augmented educational assistant. In future, a longitudinal study can be performed with the help of mobile augmented educational assistant for the entire learning concept over entire semester to understand the details about the long-term effects of learning with the help of mobile augmented educational assistant.

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APPENDIX

Analysis 1

Physics

Group Statistics					
	Technology	N	Mean	Std. Deviation	Std. Error Mean
Physics	1.00	119	64.0840	24.41678	2.23828
	2.00	119	48.4538	23.45379	2.15001

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics	Equal variances assumed	.002	.966	5.036	236
	Equal variances not assumed			5.036	235.619

Independent Samples Test					
		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Physics	Equal variances assumed	.000	15.63025	3.10362	9.51592
	Equal variances not assumed	.000	15.63025	3.10362	9.51587

Independent Samples Test		
		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Physics	Equal variances assumed	21.74458
	Equal variances not assumed	21.74464

Mathematics

Group Statistics					
	Technology	N	Mean	Std. Deviation	Std. Error Mean
Mathematics	1.00	119	66.1933	21.39035	1.96085
	2.00	119	55.8739	23.94399	2.19494

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Mathematics	Equal variances assumed	1.062	.304	3.506	236
	Equal variances not assumed			3.506	233.061

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematics	Equal variances assumed	.001	10.31933	2.94325
	Equal variances not assumed	.001	10.31933	2.94325

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Mathematics	Equal variances assumed	4.52093	16.11772
	Equal variances not assumed	4.52056	16.11810

Analysis 2

Analysis 2a

Undergraduate Students

Physics

Group Statistics					
	Technology_UG	N	Mean	Std. Deviation	Std. Error Mean
Physics	1.00	38	71.3421	23.80129	3.86108
	2.00	38	52.3947	25.87552	4.19756

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics	Equal variances assumed	.474	.493	3.322	74
	Equal variances not assumed			3.322	73.489

Independent Samples Test					
		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
					Lower
Physics	Equal variances assumed	.001	18.94737	5.70329	7.58332
	Equal variances not assumed	.001	18.94737	5.70329	7.58201

Independent Samples Test		
		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Physics	Equal variances assumed	30.31141
	Equal variances not assumed	30.31273

Undergraduate Students

Mathematics

Group Statistics					
	Technology_UG	N	Mean	Std. Deviation	Std. Error Mean
Mathematics	1.00	38	68.9211	22.89858	3.71464
	2.00	38	61.1842	23.23773	3.76966

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Mathematics	Equal variances assumed	.051	.821	1.462	74
	Equal variances not assumed			1.462	73.984

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematics	Equal variances assumed	.148	7.73684	5.29234
	Equal variances not assumed	.148	7.73684	5.29234

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Mathematics	Equal variances assumed	-2.80838	18.28206
	Equal variances not assumed	-2.80842	18.28210

Analysis 2b

Recent College Graduates Not Graduated for More Than 2 Years

Physics

Group Statistics					
	Technology_RCG1	N	Mean	Std. Deviation	Std. Error Mean
Physics	1.00	43	55.9535	25.98164	3.96216
	2.00	43	42.9302	22.61310	3.44846

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics	Equal variances assumed	.546	.462	2.479	84
	Equal variances not assumed			2.479	82.431

Independent Samples Test

		t-test for Equality of Means			
					95% Confidence Interval of the Difference
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower
Physics	Equal variances assumed	.015	13.02326	5.25268	2.57773
	Equal variances not assumed	.015	13.02326	5.25268	2.57482

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Physics	Equal variances assumed	23.46878
	Equal variances not assumed	23.47169

Recent College Graduates Not Graduated for More Than 2 Years

Mathematics

Group Statistics					
	Technology_RCG 1	N	Mean	Std. Deviation	Std. Error Mean
Mathematics	1.00	43	62.4884	20.18176	3.07769
	2.00	43	54.8372	25.26614	3.85305

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Mathematics	Equal variances assumed	2.684	.105	1.552	84
	Equal variances not assumed			1.552	80.089

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematics	Equal variances assumed	.125	7.65116	4.93135
	Equal variances not assumed	.125	7.65116	4.93135

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Mathematics	Equal variances assumed	-2.15536	17.45768
	Equal variances not assumed	-2.16236	17.46468

Analysis 2c

Recent College Graduates Graduated for More Than 2 Years

Physics

Group Statistics					
	Technology_RCG 2	N	Mean	Std. Deviation	Std. Error Mean
Physics	1.00	38	66.0263	20.82681	3.37855
	2.00	38	51.0263	21.14108	3.42954

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics	Equal variances assumed	.134	.715	3.116	74
	Equal variances not assumed			3.116	73.983

Independent Samples Test

		t-test for Equality of Means			
					95% Confidence Interval of the Difference
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower
Physics	Equal variances assumed	.003	15.00000	4.81418	5.40753
	Equal variances not assumed	.003	15.00000	4.81418	5.40750

Independent Samples Test

		t-test for Equality of Means
		95% Confidence Interval of the Difference
		Upper
Physics	Equal variances assumed	24.59247
	Equal variances not assumed	24.59250

Recent College Graduates Graduated for More Than 2 Years

Mathematics

Group Statistics					
	Technology_RCG2	N	Mean	Std. Deviation	Std. Error Mean
Mathematics	1.00	38	67.6579	21.13570	3.42866
	2.00	38	51.7368	22.71526	3.68490

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Mathematics	Equal variances assumed	.094	.760	3.163	74
	Equal variances not assumed			3.163	73.619

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematics	Equal variances assumed	.002	15.92105	5.03331
	Equal variances not assumed	.002	15.92105	5.03331

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Mathematics	Equal variances assumed	5.89196	25.95014
	Equal variances not assumed	5.89110	25.95101

Analysis 3: Between Groups Analysis

3.1 With technology

Mathematics

Between Group 1 and 2

Group Statistics					
	Sub_1_2	N	Mean	Std. Deviation	Std. Error Mean
Math_With_Tech	1.00	43	62.4884	20.18176	3.07769
	2.00	38	67.6579	21.13570	3.42866

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_With_Tech	Equal variances assumed	.050	.824	-1.125	79
	Equal variances not assumed			-1.122	76.750

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_With_Tech	Equal variances assumed	.264	-5.16952	4.59410
	Equal variances not assumed	.265	-5.16952	4.60737

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_With_Tech	Equal variances assumed	-14.31385	3.97481
	Equal variances not assumed	-14.34445	4.00541

With technology

Mathematics

Between Group 2 and 3

Group Statistics					
	Sub_2_3	N	Mean	Std. Deviation	Std. Error Mean
Math_With_Tech	1.00	38	68.9211	22.89858	3.71464
	2.00	38	67.6579	21.13570	3.42866

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_With_Tech	Equal variances assumed	1.031	.313	.250	74
	Equal variances not assumed			.250	73.530

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_With_Tech	Equal variances assumed	.803	1.26316	5.05512
	Equal variances not assumed	.803	1.26316	5.05512

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_With_Tech	Equal variances assumed	-8.80940	11.33571
	Equal variances not assumed	-8.81047	11.33678

With technology

Mathematics

Between Group 1 and 3

Group Statistics					
	Sub_1_3	N	Mean	Std. Deviation	Std. Error Mean
Math_With_Tech	1.00	38	68.9211	22.89858	3.71464
	2.00	43	62.4884	20.18176	3.07769

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_With_Tech	Equal variances assumed	1.721	.193	1.344	79
	Equal variances not assumed			1.333	74.363

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_With_Tech	Equal variances assumed	.183	6.43268	4.78624
	Equal variances not assumed	.186	6.43268	4.82397

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_With_Tech	Equal variances assumed	-3.09408	15.95944
	Equal variances not assumed	-3.17852	16.04388

With technology

Physics

Between Group 1 and 2

Group Statistics					
	Sub_1_2	N	Mean	Std. Deviation	Std. Error Mean
Physics_With_Tech	1.00	43	62.6279	22.83066	3.48164
	2.00	38	66.0263	20.82681	3.37855

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics_With_Tech	Equal variances assumed	.607	.438	-.696	79
	Equal variances not assumed			-.700	78.912

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Physics_With_Tech	Equal variances assumed	.488	-3.39841	4.87930
	Equal variances not assumed	.486	-3.39841	4.85144

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Physics_With_Tech	Equal variances assumed	-13.11041	6.31359
	Equal variances not assumed	-13.05513	6.25831

With technology

Physics

Between Group 2 and 3

Group Statistics					
	Sub_2_3	N	Mean	Std. Deviation	Std. Error Mean
Physics_With_Tech	1.00	38	71.3421	23.80129	3.86108
	2.00	38	66.0263	20.82681	3.37855

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics_With_Tech	Equal variances assumed	.254	.616	1.036	74
	Equal variances not assumed			1.036	72.719

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Physics_With_Tech	Equal variances assumed	.304	5.31579	5.13055
	Equal variances not assumed	.304	5.31579	5.13055

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Physics_With_Tech	Equal variances assumed	-4.90706	15.53864
	Equal variances not assumed	-4.91005	15.54163

With technology

Physics

Between Group 1 and 3

Group Statistics					
	Sub_1_3	N	Mean	Std. Deviation	Std. Error Mean
Physics_With_Tech	1.00	38	71.3421	23.80129	3.86108
	2.00	43	62.6279	22.83066	3.48164

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Physics_With_Tech	Equal variances assumed	.035	.852	1.680	79
	Equal variances not assumed			1.676	76.864

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Physics_With_Tech	Equal variances assumed	.097	8.71420	5.18551
	Equal variances not assumed	.098	8.71420	5.19902

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Physics_With_Tech	Equal variances assumed	-1.60730	19.03570
	Equal variances not assumed	-1.63866	19.06706

3.2 Without Technology

Mathematics

Between group 1 and 2

Group Statistics					
	Sub_1_2	N	Mean	Std. Deviation	Std. Error Mean
Math_Without_Tech	1.00	43	54.8372	25.26614	3.85305
	2.00	38	51.7368	22.71526	3.68490

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_Without_Tech	Equal variances assumed	.961	.330	.578	79
	Equal variances not assumed			.582	78.972

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_Without_Tech	Equal variances assumed	.565	3.10037	5.36691
	Equal variances not assumed	.563	3.10037	5.33146

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_Without_Tech	Equal variances assumed	-7.58221	13.78294
	Equal variances not assumed	-7.51170	13.71244

Without Technology

Mathematics

Between group 2 and 3

Group Statistics					
	Sub_2_3	N	Mean	Std. Deviation	Std. Error Mean
Math_Without_Tech	1.00	38	61.1842	23.23773	3.76966
	2.00	38	51.7368	22.71526	3.68490

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_Without_Tech	Equal variances assumed	.158	.692	1.792	74
	Equal variances not assumed			1.792	73.962

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_Without_Tech	Equal variances assumed	.077	9.44737	5.27151
	Equal variances not assumed	.077	9.44737	5.27151

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_Without_Tech	Equal variances assumed	-1.05634	19.95108
	Equal variances not assumed	-1.05643	19.95117

Without Technology

Mathematics

Between group 1 and 3

Group Statistics					
	Sub_1_3	N	Mean	Std. Deviation	Std. Error Mean
Math_Without_Tech	1.00	38	61.1842	23.23773	3.76966
	2.00	43	54.8372	25.26614	3.85305

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Math_Without_Tech	Equal variances assumed	.359	.551	1.171	79
	Equal variances not assumed			1.177	78.864

Independent Samples Test				
		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Math_Without_Tech	Equal variances assumed	.245	6.34700	5.41860
	Equal variances not assumed	.243	6.34700	5.39039

Independent Samples Test			
		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Math_Without_Tech	Equal variances assumed	-4.43844	17.13245
	Equal variances not assumed	-4.38259	17.07659

Without Technology

Physics

Between group 1 and 2

Group Statistics					
	Sub_1_2	N	Mean	Std. Deviation	Std. Error Mean
Physics_Without_Tech	1.00	43	42.9302	22.61310	3.44846
	2.00	38	50.7632	21.15251	3.43139

Independent Samples Test				
		Levene's Test for Equality of Variances		t-test for Equality of Means
		F	Sig.	t
Physics_Without_Tech	Equal variances assumed	.152	.698	-1.603
	Equal variances not assumed			-1.610

Independent Samples Test				
		t-test for Equality of Means		
		df	Sig. (2-tailed)	Mean Difference
Physics_Without_Tech	Equal variances assumed	79	.113	-7.83293
	Equal variances not assumed	78.731	.111	-7.83293

Independent Samples Test				
		t-test for Equality of Means		
		Std. Error Difference	95% Confidence Interval of the Difference	
			Lower	Upper
Physics_Without_Tech	Equal variances assumed	4.88512	-17.55652	1.89067
	Equal variances not assumed	4.86481	-17.51660	1.85075

Without Technology

Physics

Between group 2 and 3

Group Statistics					
	Sub_2_3	N	Mean	Std. Deviation	Std. Error Mean
Physics_Without_Tech	1.00	38	52.3947	25.87552	4.19756
	2.00	38	50.7632	21.15251	3.43139

Independent Samples Test				
		Levene's Test for Equality of Variances		t-test for Equality of Means
		F	Sig.	t
Physics_Without_Tech	Equal variances assumed	.912	.343	.301
	Equal variances not assumed			.301

Independent Samples Test				
		t-test for Equality of Means		
		df	Sig. (2-tailed)	Mean Difference
Physics_Without_Tech	Equal variances assumed	74	.764	1.63158
	Equal variances not assumed	71.185	.764	1.63158

Independent Samples Test				
		t-test for Equality of Means		
		Std. Error Difference	95% Confidence Interval of the Difference	
			Lower	Upper
Physics_Without_Tech	Equal variances assumed	5.42162	-9.17124	12.43440
	Equal variances not assumed	5.42162	-9.17834	12.44150

Without Technology

Physics

Between group 1 and 3

Group Statistics					
	Sub_1_3	N	Mean	Std. Deviation	Std. Error Mean
Physics_Without_Tech	1.00	38	52.3947	25.87552	4.19756
	2.00	43	42.9302	22.61310	3.44846

Independent Samples Test				
		Levene's Test for Equality of Variances		t-test for Equality of Means
		F	Sig.	t
Physics_Without_Tech	Equal variances assumed	.385	.537	1.757
	Equal variances not assumed			1.742

Independent Samples Test				
		t-test for Equality of Means		
		df	Sig. (2-tailed)	Mean Difference
Physics_Without_Tech	Equal variances assumed	79	.083	9.46450
	Equal variances not assumed	74.074	.086	9.46450

Independent Samples Test				
		t-test for Equality of Means		
		Std. Error Difference	95% Confidence Interval of the Difference	
			Lower	Upper
Physics_Without_Tech	Equal variances assumed	5.38714	-1.25833	20.18734
	Equal variances not assumed	5.43244	-1.35970	20.28871

Analysis 4: Univariate Analysis of Variance

Tests of Between-Subjects Effects

Dependent Variable: Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	33233.598[a]	11	3021.236	5.674	.000
Intercept	1644345.989	1	1644345.989	3088.133	.000
Technology	20186.846	1	20186.846	37.912	.000
Subject	2428.770	1	2428.770	4.561	.033
Participants	7185.483	2	3592.742	6.747	.001
Technology * Subject	808.055	1	808.055	1.518	.219
Technology * Participants	538.858	2	269.429	.506	.603
Subject * Participants	1439.349	2	719.674	1.352	.260
Technology * Subject * Participants	699.437	2	349.719	.657	.519
Error	247067.276	464	532.473		
Total	1918900.000	476			
Corrected Total	280300.874	475			

a. R Squared = .119 (Adjusted R Squared = .098)

Parameter Estimates						
Dependent Variable: Scores						
Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	52.395	3.743	13.997	.000	45.039	59.751
[Technology=1.00]	18.947	5.294	3.579	.000	8.544	29.350
[Subject=M]	8.789	5.294	1.660	.098	-1.613	19.192
[Participants=RCG1]	-9.465	5.138	-1.842	.066	-19.560	.631
[Participants=RCG2]	-1.368	5.294	-.258	.796	-11.771	9.034
[Technology=1.00] * [Subject=M]	-11.211	7.487	-1.497	.135	-25.922	3.501
[Technology=1.00] * [Participants=RCG1]	-5.924	7.266	-.815	.415	-20.202	8.354
[Technology=1.00] * [Participants=RCG2]	-3.947	7.487	-.527	.598	-18.659	10.765
[Subject=M] * [Participants=RCG1]	3.118	7.266	.429	.668	-11.160	17.395
[Subject=M] * [Participants=RCG2]	-8.079	7.487	-1.079	.281	-22.791	6.633
[Technology=1.00] * [Subject=M] * [Participants=RCG1]	5.838	10.275	.568	.570	-14.353	26.030

[Technology=1.00] * [Subject=M] * [Participants=RCG2]	12.132	10.588	1.146	.252	-8.674	32.937

a. This parameter is set to zero because it is redundant.

Lack of Fit Tests					
Dependent Variable: Scores					
Source	Sum of Squares	df	Mean Square	F	Sig.
Lack of Fit	.000	0	.	.	.
Pure Error	247067.276	464	532.473		

Model Development

Test of Reliability: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	189	100.0
	Excluded[a]	0	.0
	Total	189	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.957	116

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
PE1	508.02	4875.856	.610	.956
PE2	507.88	4884.703	.569	.957
PE3	507.68	4878.218	.573	.957
PE4	507.90	4889.448	.491	.957
PU1	507.32	4825.675	.739	.956
PU2	507.15	4823.531	.724	.956

PU3	507.22	4827.589	.715	.956
PU4	507.17	4818.524	.752	.956
PU5	507.09	4817.072	.731	.956
PU6	507.17	4812.237	.726	.956
EM1	508.93	5001.399	-.055	.958
EM2	508.77	4979.360	.043	.958
JF1	507.54	4890.441	.473	.957
JF2	507.50	4860.070	.596	.956
JF3	507.44	4847.035	.642	.956
JF4	507.58	4845.182	.599	.956
JF5	507.61	4851.398	.663	.956
JF6	507.82	4850.553	.658	.956
RA1	507.53	4829.165	.712	.956
RA2	507.63	4828.222	.722	.956
RA3	507.44	4829.599	.671	.956
RA4	507.59	4838.487	.682	.956
RA5	507.63	4862.020	.594	.956

OE1	508.12	4875.316	.589	.957
OE2	507.92	4921.222	.397	.957
OE3	507.92	4887.159	.557	.957
OE4	507.86	4909.251	.458	.957
OE5	507.96	4912.732	.437	.957
OE6	508.01	4890.915	.541	.957
EE1	508.33	4887.988	.559	.957
EE2	508.34	4889.057	.546	.957
EE3	508.28	4868.958	.571	.957
EE4	508.26	4871.908	.564	.957
EE5	508.02	4865.361	.321	.957
EE6	507.67	4970.202	.091	.958
PEU1	508.03	4885.084	.481	.957
PEU2	507.86	4891.442	.472	.957
PEU3	508.05	4886.939	.489	.957
PEU4	507.94	4879.187	.562	.957
PEU5	508.02	4880.718	.504	.957

PEU6	508.05	4852.753	.585	.956
COM 1	508.22	5099.312	-.432	.959
COM 2	508.14	5099.581	-.426	.959
COM 3	508.17	5139.578	-.542	.960
COM 4	508.16	5108.453	-.463	.959
EOU1	507.56	4817.322	.615	.956
EOU2	507.43	4825.460	.615	.956
EOU3	507.40	4830.646	.616	.956
EOU4	507.53	4818.835	.601	.956
SI1	506.97	4954.260	.202	.957
SI2	506.95	4949.774	.248	.957
SI3	507.01	4939.314	.285	.957
SI4	506.95	4953.907	.209	.957
SN1	507.85	4923.138	.296	.957

SN2	507.67	4916.445	.321	.957
SF1	507.96	4951.296	.180	.957
SF2	508.17	4932.865	.297	.957
IM1	508.20	4984.307	.022	.958
IM2	508.07	5016.447	-.122	.958
FC1	508.02	4887.851	.450	.957
FC2	508.21	4931.519	.264	.957
FC3	508.11	4903.195	.406	.957
PBC1	507.69	4826.001	.688	.956
PBC2	507.59	4817.095	.693	.956
PBC3	507.66	4827.342	.659	.956
PBC4	507.65	4832.113	.608	.956
PBC5	507.26	4890.345	.421	.957
C1	507.79	4877.207	.554	.957
C2	507.87	4888.818	.483	.957
C3	507.90	4863.516	.578	.956
ATT1	506.52	5024.357	-.233	.958

ATT2	506.49	5010.049	-.127	.958
ATT3	506.48	4996.804	-.042	.958
ATT4	506.58	4987.245	.023	.958
ATB1	508.16	4879.549	.506	.957
ATB2	508.06	4871.847	.560	.957
IMO1	507.89	4860.616	.644	.956
IMO2	507.84	4836.294	.715	.956
ATU1	507.92	4885.999	.549	.957
ATU2	508.02	4907.494	.442	.957
ATU3	507.89	4949.361	.235	.957
AFF1	507.33	4804.019	.759	.956
AFF2	507.12	4825.373	.692	.956
AFF3	506.66	4929.523	.264	.957
AFF4	506.90	4875.314	.496	.957
AFF5	506.83	4901.485	.355	.957
SP1	506.83	4983.539	.066	.957
SP2	506.78	4994.724	-.033	.958

SP3	506.78	4981.192	.081	.957
SA1	508.50	4902.124	.391	.957
SA2	508.26	4904.238	.413	.957
PEn1	507.54	4885.537	.541	.957
PEn2	507.22	4939.894	.258	.957
PEn3	507.48	4869.442	.646	.956
PEn4	507.68	4863.101	.614	.956
PEn5	507.68	4860.069	.634	.956
PEn6	507.45	4857.972	.635	.956
SML1	507.32	4826.624	.695	.956
SML2	507.06	4820.119	.694	.956
SML3	507.17	4813.961	.699	.956
UX1	505.28	4997.884	-.093	.957
UX2	505.33	5000.732	-.133	.957
USA1	505.61	4983.664	.069	.957
USA2	505.66	4965.534	.230	.957
DES1	505.79	4995.072	-.037	.958

DES2	505.84	4985.883	.044	.957
ACC1	505.52	5013.102	-.231	.958
ACC2	505.48	5004.006	-.135	.958
MOB1	507.08	4796.312	.715	.956
MOB2	506.94	4794.890	.701	.956
BI1	505.95	5025.929	-.259	.958
BI2	506.01	4998.394	-.059	.958
BI3	505.98	5018.436	-.197	.958
BI4	505.95	5027.312	-.256	.958
BI5	505.97	5017.079	-.191	.958
BI6	506.04	5020.227	-.210	.958

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PE1	189	6	1	7	719	3.80	.097	1.336	1.786	.188	.177	-.722	.352
PE2	189	6	1	7	745	3.94	.096	1.322	1.747	.066	.177	-.836	.352
PE3	189	6	1	7	782	4.14	.101	1.392	1.938	-.034	.177	-.944	.352
PE4	189	6	1	7	740	3.92	.106	1.456	2.120	.190	.177	-.718	.352
PU1	189	6	1	7	851	4.50	.116	1.590	2.528	-.013	.177	-.964	.352
PU2	189	6	1	7	883	4.67	.120	1.643	2.700	-.290	.177	-.895	.352

PU3	189	6	1	7	869	4.60	.118	1.623	2.635	-.468	.177	-.482	.352
PU4	189	6	1	7	879	4.65	.119	1.632	2.665	-.424	.177	-.784	.352
PU5	189	6	1	7	894	4.73	.123	1.690	2.858	-.397	.177	-.803	.352
PU6	189	6	1	7	879	4.65	.127	1.749	3.058	-.436	.177	-.758	.352
EM1	189	6	1	7	547	2.89	.117	1.611	2.595	.752	.177	-.194	.352
EM2	189	6	1	7	577	3.05	.115	1.587	2.518	.671	.177	-.222	.352
JF1	189	6	1	7	809	4.28	.109	1.495	2.235	-.036	.177	-.690	.352
JF2	189	6	1	7	816	4.32	.113	1.552	2.409	.061	.177	-.689	.352
JF3	189	6	1	7	828	4.38	.116	1.589	2.524	.007	.177	-.738	.352

JF4	189	11	1	12	802	4.24	.125	1.721	2.962	.503	.177	1.099	.352
JF5	189	6	1	7	795	4.21	.109	1.493	2.228	.087	.177	-.727	.352
JF6	189	6	1	7	756	4.00	.110	1.512	2.287	.280	.177	-.531	.352
RA1	189	6	1	7	810	4.29	.118	1.615	2.609	-.037	.177	-.844	.352
RA2	189	6	1	7	791	4.19	.117	1.602	2.567	-.047	.177	-.791	.352
RA3	189	6	1	7	828	4.38	.124	1.705	2.907	-.136	.177	-.907	.352
RA4	189	6	1	7	799	4.23	.115	1.587	2.517	-.049	.177	-.680	.352
RA5	189	6	1	7	791	4.19	.112	1.534	2.354	.140	.177	-.753	.352
OE1	189	6	1	7	700	3.70	.101	1.390	1.933	.184	.177	-.462	.352

OE2	189	6	1	7	737	3.90	.090	1.236	1.527	-.080	.177	-.401	.352
OE3	189	6	1	7	737	3.90	.096	1.319	1.740	-.038	.177	-.061	.352
OE4	189	6	1	7	749	3.96	.091	1.256	1.578	.022	.177	-.466	.352
OE5	189	6	1	7	730	3.86	.092	1.260	1.587	.295	.177	-.084	.352
OE6	189	6	1	7	720	3.81	.095	1.307	1.708	.142	.177	-.062	.352
EE1	189	6	1	7	660	3.49	.095	1.303	1.698	-.012	.177	-.360	.352
EE2	189	6	1	7	657	3.48	.096	1.319	1.740	.249	.177	-.174	.352
EE3	189	6	1	7	669	3.54	.110	1.511	2.282	.096	.177	-.625	.352
EE4	189	6	1	7	672	3.56	.109	1.492	2.227	.056	.177	-.720	.352

EE5	189	34	1	35	718	3.80	.193	2.658	7.066	8.622	.177	101.378	.352
EE6	189	6	1	7	785	4.15	.109	1.492	2.226	-.111	.177	-.631	.352
PEU1	189	6	1	7	716	3.79	.112	1.546	2.391	.037	.177	-.849	.352
PEU2	189	6	1	7	749	3.96	.108	1.482	2.195	-.085	.177	-.827	.352
PEU3	189	6	1	7	713	3.77	.109	1.497	2.241	.020	.177	-.936	.352
PEU4	189	6	1	7	734	3.88	.102	1.406	1.976	-.081	.177	-.820	.352
PEU5	189	6	1	7	719	3.80	.112	1.540	2.371	.033	.177	-.884	.352
PEU6	189	6	1	7	712	3.77	.121	1.669	2.786	.028	.177	-1.111	.352
COM1	189	6	1	7	680	3.60	.131	1.798	3.231	.325	.177	-.929	.352

COM2	189	6	1	7	695	3.68	.133	1.832	3.358	.319	.177	-1.012	.352
COM3	189	6	1	7	690	3.65	.142	1.956	3.824	.357	.177	-1.036	.352
COM4	189	6	1	7	692	3.66	.132	1.816	3.300	.374	.177	-.925	.352
EOU1	189	6	1	7	805	4.26	.145	1.995	3.980	-.172	.177	-1.305	.352
EOU2	189	6	1	7	829	4.39	.138	1.900	3.611	-.210	.177	-1.176	.352
EOU3	189	6	1	7	835	4.42	.134	1.839	3.383	-.342	.177	-1.016	.352
EOU4	189	6	1	7	810	4.29	.147	2.022	4.088	-.166	.177	-1.380	.352

SI1	189	4	3	7	916	4.85	.091	1.256	1.577	.001	.177	-1.099	.352
SI2	189	4	3	7	921	4.87	.084	1.160	1.345	.065	.177	-.898	.352
SI3	189	4	3	7	910	4.81	.092	1.264	1.599	.019	.177	-1.144	.352
SI4	189	4	3	7	920	4.87	.089	1.228	1.509	-.041	.177	-.970	.352
SN1	189	6	1	7	750	3.97	.115	1.588	2.520	.036	.177	-.625	.352
SN2	189	6	1	7	784	4.15	.117	1.611	2.595	-.112	.177	-.671	.352
SF1	189	6	1	7	730	3.86	.109	1.499	2.247	.046	.177	-.297	.352
SF2	189	6	1	7	690	3.65	.099	1.362	1.856	.054	.177	-.075	.352
IM1	189	6	1	7	685	3.62	.113	1.548	2.395	.421	.177	-.429	.352

IM2	189	6	1	7	709	3.75	.116	1.593	2.539	.399	.177	-.628	.352
FC1	189	6	1	7	718	3.80	.117	1.608	2.587	.154	.177	-.919	.352
FC2	189	6	1	7	682	3.61	.113	1.556	2.420	.297	.177	-.706	.352
FC3	189	6	1	7	701	3.71	.110	1.514	2.293	.161	.177	-.842	.352
PBC1	189	6	1	7	780	4.13	.124	1.703	2.899	.048	.177	-.888	.352
PBC2	189	6	1	7	800	4.23	.129	1.780	3.169	-.105	.177	-.877	.352
PBC3	189	6	1	7	786	4.16	.128	1.758	3.092	-.185	.177	-.943	.352
PBC4	189	6	1	7	789	4.17	.134	1.847	3.411	-.070	.177	-1.033	.352
PBC5	189	6	1	7	861	4.56	.122	1.671	2.791	-.288	.177	-.693	.352

C1	189	6	1	7	761	4.03	.105	1.449	2.100	.187	.177	-.571	.352
C2	189	6	1	7	747	3.95	.108	1.489	2.216	-.015	.177	-.550	.352
C3	189	6	1	7	741	3.92	.113	1.557	2.425	-.114	.177	-.812	.352
ATT1	189	3	4	7	1001	5.30	.075	1.025	1.050	.248	.177	-1.067	.352
ATT2	189	3	4	7	1008	5.33	.080	1.096	1.202	.212	.177	-1.267	.352
ATT3	189	3	4	7	1009	5.34	.078	1.078	1.161	.193	.177	-1.230	.352
ATT4	189	3	4	7	991	5.24	.073	1.007	1.015	.284	.177	-1.017	.352
ATB1	189	6	1	7	692	3.66	.113	1.551	2.406	-.085	.177	-.844	.352

ATB2	189	6	1	7	710	3.76	.109	1.503	2.260	.195	.177	-.600	.352
IMO1	189	6	1	7	742	3.93	.104	1.435	2.058	-.175	.177	-.670	.352
IMO2	189	6	1	7	752	3.98	.112	1.537	2.361	-.231	.177	-.498	.352
ATU1	189	6	1	7	737	3.90	.098	1.351	1.825	-.025	.177	-.187	.352
ATU2	189	6	1	7	719	3.80	.097	1.328	1.765	.104	.177	-.047	.352
ATU3	189	6	1	7	742	3.93	.090	1.231	1.516	-.238	.177	-.151	.352
AFF1	189	6	1	7	849	4.49	.127	1.752	3.070	-.205	.177	-1.085	.352
AFF2	189	6	1	7	888	4.70	.123	1.698	2.882	-.244	.177	-1.021	.352
AFF3	189	6	1	7	975	5.16	.117	1.603	2.570	-.708	.177	-.193	.352

AFF4	189	6	1	7	930	4.92	.119	1.640	2.690	-.756	.177	.040	.352
AFF5	189	6	1	7	944	4.99	.127	1.749	3.058	-.752	.177	-.226	.352
SP1	189	2	4	6	944	4.99	.058	.796	.633	.009	.177	-1.417	.352
SP2	189	2	4	6	952	5.04	.060	.821	.674	-.069	.177	-1.514	.352
SP3	189	2	4	6	952	5.04	.061	.840	.706	-.070	.177	-1.583	.352
SA1	189	6	1	7	628	3.32	.115	1.587	2.518	.321	.177	-.703	.352
SA2	189	6	1	7	672	3.56	.107	1.471	2.163	.508	.177	-.404	.352
PEn1	189	6	1	7	809	4.28	.100	1.376	1.894	-.208	.177	-.345	.352

PEn2	189	6	1	7	870	4.60	.100	1.371	1.879	-.532	.177	-.099	.352
PEn3	189	6	1	7	820	4.34	.097	1.334	1.778	-.301	.177	-.417	.352
PEn4	189	6	1	7	782	4.14	.107	1.474	2.172	-.160	.177	-.719	.352
PEn5	189	6	1	7	782	4.14	.106	1.463	2.141	-.046	.177	-.916	.352
PEn6	189	6	1	7	826	4.37	.108	1.484	2.203	-.342	.177	-.527	.352
SML1	189	6	1	7	850	4.50	.122	1.678	2.815	-.258	.177	-.694	.352
SML2	189	6	1	7	900	4.76	.127	1.748	3.055	-.506	.177	-.721	.352
SML3	189	6	1	7	879	4.65	.131	1.797	3.228	-.482	.177	-.749	.352
UX1	189	1	6	7	1236	6.54	.036	.500	.250	-.161	.177	-1.995	.352

UX2	189	1	6	7	1227	6.49	.036	.501	.251	.032	.177	-2.020	.352
USA1	189	2	5	7	1173	6.21	.054	.747	.558	-.356	.177	-1.134	.352
USA2	189	2	5	7	1164	6.16	.057	.783	.613	-.287	.177	-1.313	.352
DES1	189	2	5	7	1140	6.03	.059	.805	.648	-.058	.177	-1.453	.352
DES2	189	2	5	7	1131	5.98	.059	.809	.654	.029	.177	-1.469	.352
ACC1	189	2	5	7	1190	6.30	.049	.674	.454	-.436	.177	-.787	.352
ACC2	189	2	5	7	1198	6.34	.049	.678	.459	-.536	.177	-.752	.352

MOB1	189	6	1	7	895	4.74	.141	1.933	3.738	-.477	.177	-1.122	.352
MOB2	189	6	1	7	923	4.88	.144	1.986	3.944	-.677	.177	-.902	.352
BI1	189	3	4	7	1109	5.87	.070	.961	.924	-.276	.177	-1.025	.352
BI2	189	3	4	7	1098	5.81	.067	.926	.857	-.221	.177	-.897	.352
BI3	189	3	4	7	1104	5.84	.073	.998	.996	-.325	.177	-1.025	.352
BI4	189	3	4	7	1109	5.87	.074	1.015	1.030	-.286	.177	-1.170	.352
BI5	189	3	4	7	1105	5.85	.071	.980	.960	-.372	.177	-.909	.352

BI6	189	3	4	7	1093	5.78	.072	.995	.990	-.273	.177	-1.016	.352
Valid N (listwise)	189												

Behavioral Intention (BI) Model with the underlying constructs of Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Self-Perception (SP), Mobility (MOB) and User Experience (UX)

Model Fit Summary

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	435
Number of distinct parameters to be estimated:	76
Degrees of freedom (435 - 76):	359

Result (Default model)

Minimum was achieved

Chi-square = 451.756

Degrees of freedom = 359

Probability level = .001

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	76	451.756	359	.001	1.258
Saturated model	435	.000	0		
Independence model	29	1562.647	406	.000	3.849

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.108	.860	.831	.710
Saturated model	.000	1.000		
Independence model	.382	.511	.476	.477

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.711	.673	.923	.909	.920

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.037	.025	.047	.983
Independence model	.123	.117	.130	.000

Behavioral Intention (BI) as a standalone model

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments: 21

Number of distinct parameters to be estimated: 12

Degrees of freedom (21 - 12): 9

Result (Default model)

Minimum was achieved

Chi-square = 8.196

Degrees of freedom = 9

Probability level = .515

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	12	8.196	9	.515	.911
Saturated model	21	.000	0		
Independence model	6	37.050	15	.001	2.470

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.038	.986	.967	.422
Saturated model	.000	1.000		
Independence model	.098	.932	.905	.666

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.779	.631	1.029	1.061	1.000
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.000	.000	.077	.797
Independence model	.088	.053	.125	.039

Performance Expectancy (PE) Model with the underlying constructs of Perceived Usefulness (PU), Extrinsic Motivation (EM), Job Fit (JF), Relative Advantage (RA), and Outcome Expectance (OE)

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	435
Number of distinct parameters to be estimated:	91

Degrees of freedom (435 - 91): 344

Result (Default model)

Iteration limit reached

The results that follow are therefore incorrect.

Chi-square = 652.615

Degrees of freedom = 344

Probability level = .000

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	91	652.615	344	.000	1.897
Saturated model	435	.000	0		
Independence model	29	3981.285	406	.000	9.806

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.186	.797	.744	.631
Saturated model	.000	1.000		
Independence model	.988	.162	.102	.151

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.836	.807	.915	.898	.914
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.847	.708	.774
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.069	.061	.077	.000
Independence model	.216	.210	.223	.000

Performance Expectancy (PE) as a Standalone Construct

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	8	1.343	2	.511	.671
Saturated model	10	.000	0		
Independence model	4	204.804	6	.000	34.134

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.026	.996	.982	.199
Saturated model	.000	1.000		
Independence model	.691	.594	.323	.356

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.993	.980	1.003	1.010	1.000
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.333	.331	.333
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.000	.000	.129	.649
Independence model	.420	.372	.470	.000

Effort Expectancy (EE) as a Standalone Construct

Notes for Model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments:	21
Number of distinct parameters to be estimated:	14
Degrees of freedom (21 - 14):	7

Result (Default model)

Minimum was achieved

Chi-square = 8.170

Degrees of freedom = 7

Probability level = .318

Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	14	8.170	7	.318	1.167
Saturated model	21	.000	0		
Independence model	6	418.641	15	.000	27.909

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.058	.986	.958	.329
Saturated model	.000	1.000		
Independence model	.815	.524	.334	.375

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.980	.958	.997	.994	.997
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.467	.458	.465
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.030	.000	.098	.606
Independence model	.378	.348	.410	.000

Constructs and Questionnaires

Perceived Usefulness

1. Using AugmentED in learning the concept of Statistics would enable me to learn the concept more quickly.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Using AugmentED in learning the concept of Statistics would improve my performance.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED in learning the concept of Statistics would increase my productivity.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Using AugmentED in learning the concept of Statistics would enhance my effectiveness.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. Using AugmentED in learning the concept of Statistics would make it easier for me to learn the concept.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. I would find AugmentED in learning the concept of Statistics useful.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Perceived Ease of Use

1. Learning to operate AugmentED would be easy for me.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I would find it easy to get AugmentED to do that I want it to do.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. My interaction with AugmentED would be clear and understandable.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. I would find AugmentED to be flexible to interact with.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. It would be easy for me to become skillful at using AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. I would find AugmentED easy to use.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

<u>Performance Expectancy</u>

1. I would find AugmentED useful in my learning.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Using AugmentED enables me to accomplish learning activities more quickly.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED increases my learning productivity.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. If I use AugmentED I will increase my chances of getting A.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. Using AugmentED increases my interest in learning concept of Statistics.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

<u>Effort Expectancy</u>

1. My interaction with AugmentED would be clear and understandable.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. It would be easy for me to become skillful at using AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. I would find AugmentED easy to use.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Learning to operate AugmentED is easy for me.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. I would find the earning using AugmentED be interesting.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. I would think I would need training o learn to operate AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Perceived Playfulness/Enjoyment

1. When using AugmentED, I will not realize how the time is passing.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. When using AugmentED, I will forget the work I must do.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED will give enjoyment to me in my learning.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Using AugmentED will stimulate my curiosity.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. Using AugmentED will lead to my exploration.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. Using AugmentED will give me pleasure in learning the concept of Statistics.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Job Fit

1. Use of the AugmentED will have no effect on my performance in school. (Reverse Scoring)

Unlikely |_________|_________|_________|_________|_________|_________|_________| Likely

2. Use of the AugmentED can decrease the time needed for my important responsibilities.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Use of the AugmentED can significantly increase the quality of my output.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Use of the AugmentED can increase the effectiveness of performing the tasks.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. Use of the AugmentED can increase the quantity of my output for the same amount of efforts.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. Considering all tasks, the general extent to which use of the AugmentED could assist me in learning the concept of Statistics.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Relative Advantage

1. Using AugmentED enables me to accomplish tasks more quickly.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Using AugmentED improves the quality of the work I do.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED makes it easier to do my job.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Using AugmentED enhances my effectiveness in the school.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. Using AugmentED increases my productivity.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Outcome Expectations

1. I will increase my effectiveness in school at studying.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I will spend less time on daily school tasks.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. I will increase the quality of the output of my work at school.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. I will increase the quantity of output for the same amount of effort.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. My school friends will perceive me as competent.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

6. I will increase my chances of obtaining higher grade.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Complexity

1. Using AugmentED takes too much time from my normal duties.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Working with AugmentED is so complicated, it is difficult to understand what is going on.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED involves too much time doing mechanical operations (e.g. Data Input)

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. It takes too long to learn how to use AugmentED to make it worth the effort.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Ease of Use

1. My interaction with AugmentED is clear and understandable.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I believe it is easy to get AugmentED to do what I want it to do.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Overall, I believe that AugmentED is easy to use.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Learning to operate AugmentED is easy for me.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Social Factors

1. I use AugmentED because of the proportion of my friends who use it.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. My instructor is supportive to use AugmentED for learning Statistics.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Image

1. People in my school using AugmentED have a high profile.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Having AugmentED is a status symbol in the school.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

(Combined) Subjective Norm

1. People who influence my behavior think that I should use AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. People who are important to me think that I should use AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Perceived Behavioral Control

1. I have control over using AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I have the resources necessary to use AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. I have the knowledge necessary to use AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Given the resources, opportunities and knowledge it takes to use AugmentED, it would be easy for me to use it.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

5. AugmentED is not compatible with the other systems I use.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

Facilitating Conditions

1. Guidance was available to me in the selection of the system.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

2. Specialized instructions concerning AugmentED were available to me.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

3. A specific person (or group) is available for assistance with difficulties regarding AugmentED.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

Compatibility

1. Using AugmentED is compatible with all aspects of my learning.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

2. Specialized instructions concerning AugmentED were available to me.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

3. A specific person (or group) is available for assistance with difficulties regarding AugmentED.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

(Combined) Attitude toward Behavior

1. I like/dislike the idea of using AugmentED.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

2. Using AugmentED is pleasant / unpleasant.

Likely |__________|__________|__________|__________|__________|__________|__________| Unlikely

Intrinsic Motivation

1. I find AugmentED to be enjoyable.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. The process of using AugmentED is pleasant.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Affect Toward Use

1. AugmentED makes the work more interesting.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. Working with AugmentED is fun.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. AugmentED works okay for some concepts, but not for the concepts I want to learn.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Affect

1. I like working with AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I look forward to those aspects of my studies that require me to use AugmentED.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. Using AugmentED is frustrating for me. (Reverse Scoring)

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

4. Once I start working with AugmentED, I find hard to stop.

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

5. I get bored quickly when using AugmentED. (Reverse Scoring)

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Mobility

1. I can see myself carrying this device in the classes

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I can use this device as my primary information and content presentation device

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Self-Efficacy

1. I can see myself using this technology without any help

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. I can see myself performing better using this technology

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Extrinsic Motivation

1. By using AugmentED I can see myself getting better grades

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. By using AugmentED I can see myself getting better grades consistently in the future

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Self-Management of Learning

1. By using AugmentED, I can see myself organizing my educational goals better

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

2. By using AugmentED, I can see myself sorting and prioritizing my goals better

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

3. By using AugmentED, I can teach myself with little help of the instructor

Likely |_________|_________|_________|_________|_________|_________|_________| Unlikely

Phase 2 Ethnographic Research Survey Document

Science

Science

Please select the Subjects you have taken in your Engineering degree program	What was the difficulty level of the subjects?	How interested were you to learn these subjects and the advanced subjects based of these subjects?	If your answer for previous question is between 1 and 3,can you please tell us what were the reasons	Select some of the things that would have increased your understanding and the interest to learn these subjects	Please select the concepts which were the most difficult to learn
General Physics I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Measurements and Vectors, Motion in One Dimension Motion in One, Two and Three Dimensions Newtons Laws Applications of Newtons Laws Work and Kinetic Energy Conservation of Energy Conservation of Linear Momentum Rotation Angular Momentum
General Physics II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Temperature First Law of Thermodynamics Kinetic Theory of Gases Second Law of Thermodynamics Mechanical Oscillations Wave Motion Sound Waves Superposition and Standing Waves Electromagnetic Waves Light and Geometric Optics Image Formation Interference - Light Waves Diffraction Patterns and Polarization
General Chemistry I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Matter and Measurement Atoms, Molecules and Ions Formulas, equations and moles Reactions in aqueous solutions Periodicity and atomic structure Ionic bonds and main group chemistry Covalent Bonds and molecular structure

General Chemistry II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Heat, energy, 1st law of thermodynamics, expansion work Energy, enthalpy, enthalpies of physical and chemical change Calorimetry, heat capacity, Hess's law Heats of formation, bond dissociation enthalpies, combustion Introduction to entropy and Gibb's (free) energy Gases, pressure, gas laws, ideal gas law,stoichiometric relationships with gases, partial pressure,Dalton's law,kinetic molecular theory of gases, diffusion,effusion, real gas behavior Earth's atmosphere / inhaled anesthetics Polar covalent bonds, dipole moments, intermolecular forces Liquid properties, changes of state, vapor pressure Solids and phase diagrams Solutions, energy changes, units of concentration Solubility, colligative properties, Raoult's law, colligative properties, fractional distillation Nature of organic molecules, structures, shapes, alkanes Naming alkanes, cycloalkanes, reactions of alkanes Functional groups; reactions of alkenes, alkynes, and aromatics Alcohols, ethers, amines, ketones, aldehydes, carboxylic acids Esters, and amides, synthetic polymers
General Chemistry III	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Chemical Kinetics Chemical Equilibrium Aqueous Equilibria: Acids and Bases Applications of Aqueous Equilibria Thermodynamics: Entropy, Free Energy, and Equilibrium Electrochemistry
Organic Chemistry I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Alkane names and Synthesis Organic Synthesis Alkane reactions/ Stereochemistry SN1/ E1, SN2/ E2 Aromatic Names
Organic Chemistry II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Substitution reactions IR/Aromatics NMR Alcohols Ethers Acids Acid Derivatives

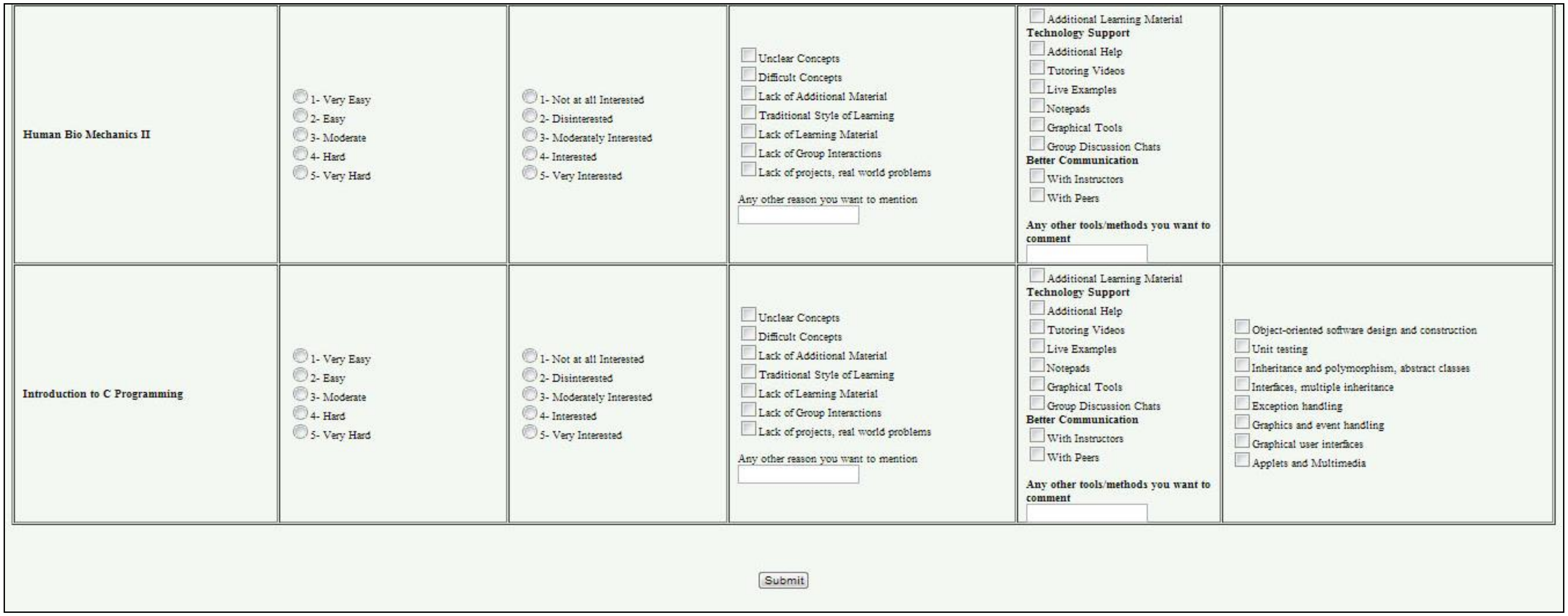
Continue

Technology

Technology

Please select the Subjects you have taken in your Engineering degree program	What was the difficulty level of the subjects?	How interested were you to learn these subjects and the advanced subjects based of these subjects?	If your answer for previous question is between 1 and 3, can you please tell us what were the reasons?	Select some of the things that would have increased your understanding and the interest to learn these subjects	Please select the concepts which were the most difficult to learn
Medical Imaging	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Generation of Photon Radiation Interaction of Photons with Matter Radiation Detection Radiation Protection Plain Radiography Image Quality MTF
Data Structures and Algorithms	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	
Digital Circuit Design	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	

Bioelectronics I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Electrical Theory - Nature of Electricity, Electrical Standards & Conventions Magnetism, Electromagnetism, Transformers Ohm's Law (Current Voltage Resistance) Generators, Motors, Servos, Stepper Motors Semiconductors & Diodes Optoelectronics DC Circuits - Ohm's Law, Kirchhoff's Laws, Thevinen & Norton Circuits AC Circuits and RMS Voltages & Currents Capacitors Inductors Transformers
Bioelectronics II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	DC circuits, AC circuits, power supplies complex impedances, RLC filters PN junctions and semiconductors Diode applications Bipolar Junction Transistors (BJT) Field effect transistors (FET) oscillators and waveform generators positive and negative feedback operational amplifiers negative feedback and op amp characteristics and applications digital electronics and integrated circuits large signal and non linear amlifiers Voltage regulators, switching circuits, multivibrators, timers digital logic circuits and logic gates
Human BioMechanics I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	



Human Bio Mechanics II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	
Introduction to C Programming	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Object-oriented software design and construction Unit testing Inheritance and polymorphism, abstract classes Interfaces, multiple inheritance Exception handling Graphics and event handling Graphical user interfaces Applets and Multimedia

Submit

Engineering

Engineering					
Please select the Subjects you have taken in your Engineering degree program	What was the difficulty level of the subjects?	How interested were you to learn these subjects and the advanced subjects based of these subjects?	If your answer for previous question is between 1 and 3,can you please tell us what were the reasons?	Select some of the things that would have increased your understanding and the interest to learn these subjects	Please select the concepts which were the most difficult to learn
Linear Systems I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Review of Complex Numbers Continuous-Time Signals Continuous-Time Systems The Laplace Transform The Fourier Series The Fourier Transform
Linear Systems II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Review of Complex Numbers Discrete-Time Signals and Systems Time-Domain Analysis of Discrete-Time Systems Sampling Theory Chapter The Z-Transform Chapter Fourier Analysis of Discrete-Time Signals & Systems Digital Filter Design & Windowing

Devices and Circuits	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Semiconductor Diodes Diode Applications Field effect transistors FET Biasing FET Amplifiers Bipolar Junction Transistor BJT DC Biasing
Circuit Analysis I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Electric charge, voltage, energy, and power. Linear DC circuits using Ohm's Law, Kirchhoff's voltage law (mesh analysis), and Kirchhoff's current law (nodal analysis) Network analysis techniques: superposition, source transformations, and Thevenin and Norton's theorems. RL, RC and RLC circuits. Steady-state analysis of linear AC circuit. DC and AC power calculations including power factor correction.
Circuit Analysis II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Sinusoidal steady-state (frequency domain) analysis; use of phasors; passive circuit elements in the frequency domain;Kirchhoff laws Steady state analysis; Thevenin & Norton equivalent; node voltage analysis and mesh circuit analysis. Sinusoidal steady state power calculations; instantaneous and average power; RMS calculations; reactive power; power factor improvement; design for maximum power transfer. Introduction to frequency selective circuits; frequency response; RC and RL low pass and high pass passive filters. RLC passive band pass and band reject filters. Mutual inductance and transformers including self and mutual inductance linear and ideal transformers. Balanced three-phase circuits, three-phase voltage and current; analysis of Y - Y and Y - Delta circuits. Balanced three-phase circuits; power calculations.

Digital Signal Processing	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Designing of digital signal processing algorithms for sampling rate conversion Polyphase analysis Designing and analyzing filter banks Application of time-frequency representations to data sequences Application of wavelet transforms to data sequences Design and simulation of discrete-time filter implementations Designing digital down-conversion Fast Fourier transforms
Thermodynamics	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Properties of pure Substances Energy, Energy Transfer, and General Energy Analysis Energy Analysis of closed systems Mass and energy analysis of control volumes Second Law of thermodynamics Entropy
Statics	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Statics of Particles Equivalent Systems Equilibrium of rigid bodies Centroids Analysis of structures Forces in beams Friction Moments of Inertia

Dynamics	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Rectilinear motion of particles Newton's Second law of motion Principles of work and energy Kinematics of rigid bodies Equations of motion for a rigid body Principles of work and energy for a rigid body
Fluid Dynamics	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Units, Experimental Uncertainty, Velocity & Stress field, Viscosity Fluid Motion Forces: on submerged surfaces, curved surfaces Conservation of mass and momentum Control volume, differential analysis Euler's & Bernoulli equations Dimensional analysis, Similarity & Model Studies, Viscous flow between platesShear stress,Velocity profile, Flow in pipes, Head loss – Major Flow meters, Flow measurements Boundary layers, Momentum Integral Equation, Boundary layers, Momentum Integral Equation Drag, Streamlining, Lift, Fluid machinery, Turbomachinery analysis Euler Turbomachine Equation, Blowers and Fans, Propellers and Wind-Power Machines Compressible flow, Speed of Sound, Converging-Diverging Nozzle Compressible flow with friction, Compressible flow with heat exchange, Normal shocks
System Dynamics	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Rigid Bodies Springs and dampers State Variables Electromechanical Systems Fluid and Thermal Systems Frequency domain Transient response and block diagrams

Thermodynamics of Materials	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Entropy from the perspective of statistical mechanics Calculation of the enthalpy of a chemical reaction as a function of temperature The thermodynamic origin of 2-phase regions on a phase diagram The thermodynamic origin of an invariant point in a phase diagram Application of Maxwell's equations Ellingham diagrams

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Mathematics

Maths

Please select the Subjects you have taken in your Engineering degree program	What was the difficulty level of the subjects?	How interested were you to learn these subjects and the advanced subjects based of these subjects	If your answer for previous question is between 1 and 3,can you please tell us what were the reasons?	Select some of the things that would have increased your understanding and the interest to learn these subjects	Please select the concepts which were the most difficult to learn
Calculus I	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Limits and Derivatives Differentiation Rules Applications of Differentiation Integrals
Calculus II	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Parametric Curves Indeterminate Forms and L'Hospital's Rule Integrals Applications of Integration Infinite Sequences and Series Vectors and the Geometry of Space Curves in Polar Coordinates Areas and Lengths in Polar Coordinates
Calculus III	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Vector Functions Partial Derivatives Multiple Integrals Vector Calculus

Statistics For Engineers	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Random Variables and Probability Distributions Discrete Probability Distributions and Probability Mass Functions Uniform Distribution, Binomial Distribution, Poisson Distribution Continuous Probability Distributions and Probability Density Functions Uniform Distribution, Exponential Distribution, Normal Distribution Central Limit Theorem, Sampling Distributions, and Interval Estimates Statistical Inference: Parameter Estimation (Mean and Variance) Correlation & Regression Statistical Inference: One Sample Hypothesis Testing (Z Test and t-Test) p-Values and Type I & II Errors Statistical Inference: One-Sided and Two-Sided Hypothesis Testing Statistical Inference: Two Sample Hypothesis Testing (Independent and Dependent {Paired t-test}) Statistical Inference: Hypothesis Testing - continued Analysis of Variance (One-Way and Two-Way ANOVA's)
Differential Equations with Matrix Algebra	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Solutions and direction fields Separation of variables Numerical approximation methods Linear differential equations First order linear differential equations Linear models: Mixing and cooling Logistic differential equation Matrices: Sums and products Systems of linear equations Matrix inverse Determinants and Cramer's Rule Vector spaces and subspaces Span and basis Second order linear differential equations Real roots of the characteristic equation Complex roots of the characteristic equation Undetermined coefficients Forced oscillations Eigenvalues and eigenvectors, Diagonalization Systems of differential equations Systems of linear differential equations Linear systems with real eigenvalues Decoupling Laplace transform and its inverse Solving ODEs by Laplace transform Step function and delta "function Convolution integrals and transfer functions

Introduction to Mathematics for Engineering	1- Very Easy 2- Easy 3- Moderate 4- Hard 5- Very Hard	1- Not at all Interested 2- Disinterested 3- Moderately Interested 4- Interested 5- Very Interested	Unclear Concepts Difficult Concepts Lack of Additional Material Traditional Style of Learning Lack of Learning Material Lack of Group Interactions Lack of projects, real world problems Any other reason you want to mention	Additional Learning Material **Technology Support** Additional Help Tutoring Videos Live Examples Notepads Graphical Tools Group Discussion Chats **Better Communication** With Instructors With Peers **Any other tools/methods you want to comment**	Linear and Quadratic Equations Trigonometry: One-Link and Two-Links Planar Robots 2-D Vectors and Complex Numbers In Engineering Sinusoids and Harmonic Signals in Engineering Systems of Equations and Matrices in Engineering Introduction to Derivatives in Engineering Application of Derivatives - Velocity and Acceleration Application of Derivatives - Electrical Circuits Application of Derivatives - Deflection of Beams Introduction to Integrals in Engineering Application of Integrals in Statics Application of Integrals in Dynamics Application of Integrals in Electrical Circuits Introduction to Differential Equations - The Leaking Bucket Application of Differential Equations - Mechanical Systems Application of Differential Equations - Electrical Systems

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